TouchStory: Interactive Software Designed to Assist Children with Autism to Understand Narrative

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ABSTRACT

The work described in this thesis falls under the umbrella of the Aurora project (Aurora 2000). Aurora is a long-term research project which, through diverse studies, investigates the potential enhancement of the everyday lives of children with autism through the use of robots, and other interactive systems, in playful contexts. Autism is a lifelong pervasive disability which affects social interaction and communication. Importantly for this thesis, children with autism exhibit a deficit in *narrative comprehension* which adversely impacts their social world. The research agenda addressed by this thesis was to develop an interactive software system which promotes an understanding of narrative structure (and thus the social world) while addressing the needs of *individual* children. The conceptual approach developed was to break down narrative into proto-narrative components and address these components individually through the introduction of simple game-like tasks, called t-stories, presented in a human-computer interaction context. The overarching hypothesis addressed was that it is possible to help children with autism to improve their narrative skills by addressing proto-narrative components independently.

An interactive software system called TouchStory was developed to present t-stories to children with autism. Following knowledge of the characteristics and preferences of this group of learners TouchStory maintained strong analogies with the concrete, physical world. The design approach was to keep things simple, introducing features only if necessary to provide a focussed and enjoyable game. TouchStory uses a touch-sensitive screen as the interaction device as it affords immediate direct manipulation of the t-story components. Socially mediated methods of requirements elicitation and software evaluation (such as focus groups, thinking aloud protocols, or intergenerational design teams) are not appropriate for use with children with autism who are not socially oriented and, in the case of children with 'lower functioning' autism, may have very few words or no productive language. Therefore a new strategy was developed to achieve an inclusive, child-centred design; this was to interleave prototype development with evaluation over several long-term trials. The trials were carried out in the participants' own school environments to provide an ecologically valid contextual enquiry. In the first trial 18 participants were each seen individually once. The second and third trials were extended studies of 12 and 20 school visits with 12 and 6 participants respectively; each participant was seen individually on each school visit, provided that the participant was at school on the day of the visit.

Evaluation was carried out on the basis of video recordings of the sessions and software logs of the on-screen interactions. Individual learning needs were addressed by adapting the set of t-stories presented to the participant on the basis of success during recent sessions. No ordering of difficulty among the proto-narrative categories could be known *a priori* for any individual child, and may vary from child to child. Therefore the intention was to gradually, over multiple sessions, increase the proportion of t-stories from proto-narrative categories which the *individual* participant found challenging, while retaining sufficient scope for the expression of skills already mastered for the session to be enjoyable and rewarding. The adaptation of the software was achieved by introducing a simple adaptive formula, evaluating it over successive long terms trials, and increasing the complexity of the formula only where necessary.

Results indicate that individual participants found the interactive presentation of the simple game-like tasks engaging, even after repeated exposures on as many as 20 occasions. The adaptive formula developed in this study did, for engaged participants, focus on the proto-narrative categories which the participant needed to practice but was likely to succeed; that is it did target an effective learning zone. While little evidence was seen of learning with respect to the fully developed narratives encountered in everyday life, results strongly suggest that some participants were actively engaged in self-directed, curiosity-driven activity that functioned as learning in that they were able to transfer knowledge about the appropriateness of particular responses to previously unseen t-stories.

This thesis was driven by the needs of children with autism; contributions are made in a number of cognate areas. A conceptual contribution was made by the introduction of the proto-narrative concept which was shown to identify narrative deficits in children with autism and to form a basis for learning. A contribution was made to computational adaptation by the development of a novel adaptive formula which was shown to present a challenging experience while maintaining sufficient predictability and opportunities for the expression of skills already mastered to provide a comfortable experience for children with autism. A contribution was made to software development by showing that children with autism may be included in the design process through iterative development combined with long term trials. A contribution was made to assistive technology by demonstrating that simplicity together with evaluation over long term trials engages children with autism and is a route to inclusion. We cannot expect any magic fixes for children with autism, progress will be made by small steps; this thesis forms a small but significant contribution.

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'In theory, it is simple enough to make any learning enjoyable: find out what the students' skills are and what their level is, ..., and then devise limited but gradually increasing opportunities for the expression of those skills' (Csikszentmihalyi 2000, page 205).

1. CHAPTER 1: INTRODUCTION

The work described in this thesis falls under the umbrella of the Aurora project (Aurora 2000). Aurora is an ongoing, long-term research project which, through various diverse studies, investigates the potential enhancement of the everyday lives of children with autism through the use of robots, and other interactive systems, in playful contexts. The work described in this thesis forms one such study, related to, but distinct from, other studies carried out under the Aurora umbrella. The work was carried out in part-time mode, initially while I was a full-time computer science lecturer and latterly in my retirement; it met a need for new challenges and new areas of engagement. I brought to it some knowledge of a variety of computer science topics (my expertise being in database theory), and an appreciation of the impossibility of ever truly knowing or being known by another. As Scott McCloud puts it '*No human being can ever know what it is like to be you from the inside*' (McCloud 1993, page 194). At the beginning of this work I had no recent dealings with young children, and no dealings with persons whom I knew to be on the autistic continuum. Learning about modern school environments, and how best (to try) to interact with children with autism were part of my learning process. I was also unaware of the domain of research broadly called artificial life, but my imagination was captured by a module taken in 2002 (in my first degree I specialised in micro-ecology), and I was interested to explore, however tangentially and minimally, a biologically inspired approach to software system design based on simplicity and gradual adaptation.

1.1 Preamble / introductory remarks

This thesis is concerned with narrative and autism; I begin by retelling a favourite story[1], which I heard told by Rita Jordan during her keynote presentation at the 7th International Autism-Europe Congress, held in Lisbon in 2003 (Jordan 2003). It is retold here as it

[1] Any failures of recall are, of course, mine.

introduces three topics which will be returned to later in this thesis, these being: the format of stories that are 'worth telling'; the nature of autism; and the reasons why people tell stories. Jordan writes widely on the subject of the education of children with autism, for example (Jordan & Powell 1995; Jordan 1999; Jordan & Jones 1999). The story was as follows:

She told of a time when she was in Japan and a little unsettled. Her friend and colleague wrote to her, and in that letter was a story. The friend had been working with a group of children with autism; she had been working on joint attention (which children with autism find difficult). Later, the friend had taken the children to the local park. In the park was a squirrel sitting on a litter-bin (a trash can). "Look", said one little boy excitedly, pointing to the squirrel (this was good; an invitation to joint attention, and a remote reference by pointing), then the boy said "someone has thrown away a ***perfectly good squirrel****". This, Rita Jordan observed, is funny but sad, for it somehow encapsulates what autism is all about. It is not, she said, that we (people not diagnosed with autism) consider that the squirrel* ***might*** *have been thrown away, but reject the idea as unlikely; rather, we never have the thought at all.*

This story demonstrates the illuminating and explanatory power of narrative. The inner narrative (as told by the friend) provides a powerful picture of what it is like to work or be with children with autism. It gives an insight into the inner world of a particular child with autism and gives a tiny inkling of what it is like to be such a child, while at the same time illuminating the limits of empathy from both perspectives. These are the reasons why it was a good story to tell at a conference. However, these insights were not the purpose of the original, inner, narrative; Rita Jordan already had these insights. Rather, the friend's purpose was to bond, to cheer and to domesticate the experience of being unsettled in a foreign land by sending a story from a commonly understood genre, which could be called the 'isn't life just like that' genre. Thus, this small example illustrates some facets of narrative and its fundamental importance to human social interaction and well-being.

Central to this thesis is the role of narrative in meaning making, especially in constructing and conveying social meaning, and in attributing meaning to our own lives. This is grounded in the work of Bruner (1986; 1990) who proposed two modes of thought, one which relies on formal logic and concrete empirical evidence, and the other, narrative, mode of thought which relies on interpretive strategies, and for which internal consistency and 'believability' are more important than established facts. Bruner (1991) proposed that human beings create a personal reality, particularly social reality, by constructing stories using a narrative mode of thought. This basic human ability develops early in childhood; most children have a tacit understanding of the concept of a story from an early age. Indeed Bruner and Feldman proposed a preverbal narrative transactional format which can be seen in the simple peek-a-boo game commonly played with babies (Bruner & Feldman 1993; Dautenhahn 2002). This narrative transactional format provides a framework in which to structure and interpret everyday experience, especially social experience, and gives a context in which to fit new or surprising events (Bruner 2002).

The importance of narrative to human beings is emphasised by authors from many disciplines, as illustrated by the following quotations: *'The human being is a story telling machine. The self is a story.'* (Broks 2003, page 41); *'Narrative is among the most important social resources for creating and maintaining personal identity*' (Linde 1993, page 93); '*It is a way to domesticate human error and surprise'* (Bruner 2002, page 90); *'Narrative recognises the meaningfulness of individual experiences by noting how they function as parts of a whole'* (Polkinghorne 1988, page 36); '*Narrative is the principal way in which our species organizes its understanding of time*' (Porter Abbott 2002, page 3); '*…we rely on works of fiction, in any medium, to help us understand the world and what it means to be human*' (Murray 1997b, page 26). All agree on its crucial importance; '*We engage in narrative so often and with such unconscious ease that the gift for it would seem to be everyone's birthright*' (Porter Abbott 2002, page 1). These quotations were selected from many possibilities, not to advance a developing argument, but rather to illustrate the widespread view of the importance of narrative in building our personal understanding of the (social) world and of ourselves.

1.2 Overview of the research

Autism is a pervasive disability affecting social understanding and social communication (NAS 2008a). Research has shown a deficit in the comprehension and creation of narrative in children with autism (Capps, Losh & Thurber 2000; Sacks 1996; Tager-Flushberg & Sullivan 1995). This narrative deficit may be regarded as fundamental, causal rather than symptomatic of the difficulties of social understanding and communication found in autism (Bruner & Feldman 1993; Dautenhahn 2002; Hutto 2003). The current work is, then, set in the context of the following overarching goal:

Overarching goal: to find ways to improve the everyday social world of individual children with autism by improving their grasp of narrative, allowing them to fit social experience into a narrative pattern and thus inhabit a more socially meaningful and consistent world.

This thesis presents progress towards an adaptive interactive software game, called TouchStory, designed specifically for children with autism. However, autism is a spectrum condition, and children with autism form a very diverse group, each child being autistic in his or her 'own way'. The differences to be found among children with autism are powerfully illustrated in (Powell 1999). The research agenda addressed by the design of TouchStory was, then, to develop an interactive software system for children with autism which both identifies specific narrative deficits and enhances narrative comprehension by addressing the needs of *individual* children. TouchStory was implemented in Java, with a Microsoft Access database as the persistent data store. The approach to the development of TouchStory was iterative; an elaboration cycle of three trials in which TouchStory was used by children with autism. In the first trial, which was designed to test the general concepts, 18 participants each used TouchStory for a single session; the second and third trials, being further rounds in the iterative cycle, were extended studies of 12 and 20 school visits with 12 and 6 participants respectively. In total the three trials comprised some 280 individual sessions.

1.3 Research goals

In this thesis the term *proto-narrative* is used to mean a sequence which presents one aspect of narrative in contrast to the fully developed narratives of everyday life. The conceptual approach taken in the design of TouchStory was to address components of narrative in isolation by using proto-narratives, and to vary them independently thus providing the possibility of targeted practice and learning opportunities for individual children. This approach is in keeping with the tendency of children with autism, when their attention is divided, to focus on matters of detail rather than attending to the general picture, that is, they tend to seek cohesion at a local, detailed level, rather than seek global cohesion (Plaisted, Swettenham & Rees 1999). As previously mentioned, autism is a spectrum disorder and children with autism form a very diverse group. Consequently, the aim of the current work was to develop an adaptive interactive software system that not only identifies specific proto-narrative deficits in individual children but also balances the needs of *individual* children with respect to those proto-narrative categories which they need to practice and their need for sufficient success for the experience to be enjoyable.

The overall hypothesis for this work is then:

Hypothesis H0: it is possible to help children with autism to improve their narrative skills by breaking down narrative into proto-narrative components and addressing these components individually. Further, the presentational and logging facilities possible in a software system render it feasible to reflect individual abilities, and thus address individual learning needs.

This thesis is concerned with providing such help by means of an interactive software system designed specifically for children with autism. The fundamental research question arising from *hypothesis H0* is this: is it indeed possible to identify components of narrative and provide representations of them such that each component can be considered independently? This matter is addressed in chapter 3, but if for now it is assumed to be so, the following research questions pertain:

1. Is it possible for an interactive learning environment to present components of narrative in a form suitable for children with autism?
    - 1.1. Would children with autism be able to use such a system?
    - 1.2. Would children with autism be engaged, and enjoy using the system as intended (rather than for some other purpose)?
    - 1.3. Would a computer-based presentation have any adverse impact when compared with a similar activity in the real world?
2. Does skill with narrative components reflect skill with the narratives of everyday life?
3. Do children with autism, as individuals, not as a population, find some components of narrative more difficult than others?
4. Can such a system reflect individual abilities with respect to components of narrative and thus address individual learning needs, given that an ordering of difficulty is not known *a priori* for any individual child, and may differ among children?
5. Would children with autism learn from using such a system? In particular does learning, if any, transfer to other related tasks or indeed generalise to the real world, bringing about improved skill in the comprehension and construction of the fully developed narratives encountered in everyday life?

1.3.1 Domain of research

The work done is in the tradition of assistive technology which is described Clarkson, Langdon and Robinson (2006, page v) as ranging from *'the identification and capture of the needs of users, through to the development and evaluation of truly usable and accessible systems for users with special needs'*. The current study spanned this range in microcosm. The aim was not to render task-based assistance as may be appropriate in the case of a human being who, for example, has difficulty seeing or climbing the stairs. Rather, following concepts of cognitive technology proposed by Gorayska et al. (Goldman, O'Banion Varma & Sharp 1999; Gorayska, Marsh & Mey 2001; Gorayska & Mey 2002) the approach was to work towards a social cognitive prosthesis, where a cognitive prosthesis is defined by Gorayska et al. (2001) as a tool which takes a human-being beyond his or her cognitive limits. The study was further informed by the observation from cognitive technology (Gorayska, Marsh & Mey 1997) that users adapt to, and are changed by, their tools, and while mind-changes in some domains (for example, learning or overcoming cognitive impairment) might be desirable, other changes do not necessarily benefit the user. A characteristic of children with autism is that they have great difficulty in being flexible and adaptable, therefore an aim was that any requirement for the child to adapt to the software system be minimized (except in beneficial ways just mentioned), and further, that the software system should adapt to the individual child.

The study draws on a number of research domains. In particular it relies on work in the disciplines of:

- Narrative, what it is, how it may be conveyed, and its importance to human beings as individuals and as social beings;
- Autism, the diverse characteristics and needs of children with autism;
- Assistive technology, which in the case of cognitive assistance may merge with or draw from educational disciplines.

A glossary of words introduced in this thesis, and words used with special meaning is given in Appendix A.

1.3.2 Methods of enquiry

In this section the methodological approach taken to the design and evaluation of TouchStory is introduced and reasons are given for this approach rather than others.

The approach was motivated by two factors. First, as previously mentioned, children with autism form a diverse group both in general and with respect to the expression of autism. Second, autism is a social disability rendering social collaboration, or even situations in which questions are asked and answered, bewildering or even frightening.

The methodological approach taken to the design and evaluation of TouchStory was child-centred and observational. The development strategy was, iteratively, to design and create a TouchStory prototype and then observe real users, that is, children with autism, interacting with the prototype over successive long-term studies. Evaluation was based on analysis of video recordings taken during TouchStory sessions and, in later versions of TouchStory, on analysis of software logs of on-screen activity. The participants were seen as individual cases rather than as a population representative of all children with autism. That is, as multiple single-case studies rather than a single parametric statistical study.

Turning first to the matter of the participants, the assistive tradition tends to a case-based approach or studies with a small number of participants as by definition assistive technology and universal access are concerned with outliers in contrast to population norms. This is particularly pertinent in the case of autism, and such an approach has been taken by a number of researchers investigating the use of interactive robots or software as assistive technologies in the case of autism. Stirling and Barrington (2007) report a study into the written narratives of one child with autism. Dautenhahn and Werry refer to a number of studies which consider the therapeutic potential of using interactive robots with children with autism (Dautenhahn & Werry 2004); Robins and Dautenhahn report work with four children with autism which investigates the impact that the appearance of a robot ('doll-like' or 'robot-like') has on child-robot interaction (Robins & Dautenhahn 2006); Heerera and Vera recommend a case-based approach in their work on teaching abstract concepts such as space to children with autism (Heerera & Vera 2005); Grynszpan et al. report working with eight high-functioning teenagers with autism in (Grynszpan, Martin & Nadel 2005), and others. In the words of Hobson, '*There is no better way to begin to understand people, whether 'normal' or disabled, whether adult or child, than to observe and examine a few individuals very closely*' (Hobson 2002, page 9). The same may be said of understanding people's interaction with assistive technology.

Turning now to information gathering techniques, the approach taken in this study was observational; interactions with TouchStory were recorded using both video-recording and software logging. An ethological, observational approach has been taken to the study of autism itself for more than 30 years (Pedersen, Livoir-Petersen & Schelde 1989; Tinbergen 1973). Tinbergen, in his Nobel lecture, refers to ethology, which is the study of animals, including human-beings, in more or less natural environments, as 'watching and wondering' (Tinbergen 1973). He stresses that he and his co-workers revived rather than invented the technique and cites Darwin as the first to apply ethology as a scientific method used in the study of human-beings. Others have since taken observational approaches to the study of autism, for example Tardif et al. (1995) analysed micro-behaviours of children with autism observed in playful, natural environments. Inspired by (Tardif et al. 1995), Dautenhahn and Werry (2002) proposed the analysis of micro-behaviours in the context of the Aurora project, not as a means to study the nature of autism, but rather as a means to evaluate robot-human interaction as an assistive technology for children with autism. They noted that this inherently observational approach transfers to other contexts and is effective where direct inquiry (e.g. questionnaires or interviews) is not suitable or is too intrusive (for example children who do not speak, or do not respond well to situations in which questions are asked and answered), or where responses are likely to be biased. They note also that both qualitative and quantitative techniques may be used in the analysis of video-recordings, but that quantitative analysis may be limited in this application area because, as previously mentioned, samples are usually small and heterogeneous.

Since 2002 an observational approach has been adopted by a number of researchers investigating robot-human interaction or interactive software as assistive technologies in the case of autism. Robins et al. used an observational approach using video recordings in several studies while investigating the potential of a small humanoid robot as an assistive technology for children with autism (Robins et al. 2004; Robins, Dautenhahn & Dubowski 2005; Robins & Dautenhahn 2006; Robins et al. 2007), Grynszpan et al. whose overarching aim is to devise guidelines for creating software for people with autism, used an observational approach based on software logs, and in later studies video recordings, while investigating the impact of output modalities (text, image, synthetic voice) on the effectiveness of educational software designed for teenagers with high functioning autism (Grynszpan, Martin & Nadel 2005; 2007). François et al. used an observational approach while using an AIBO robot (which takes the form of a small dog) to investigate a novel method for the recognition, in real time, of play styles adopted by individual of children with autism while interacting with the robot (François, Polani & Dautenhahn 2008). Returning to the nature of autism; following work of Dautenhahn and her colleagues cited above, and other studies, Stanton et al. (2008) investigated the role of robotic animals in the social development of children with autism from a psychology perspective using behavioural analysis techniques. They developed a behavioural coding scheme for child-artefact interactions where the artefact was in one case an AIBO and in the other case a mechanical toy dog. In common with other studies their sample was small, consisting of 11 participants; they particularly comment on the difficulty of obtaining participants and consequent limitations that places on quantitative analysis.

The methods of enquiry adopted in the current study thus followed a body of experience, from diverse sources, which is concerned with assistive technology in the case of autism. The approach contrasts with other child-centred approaches which are highly socially mediated, for example Druin et al. have included child users (for example, those in paediatric rehabilitation) in the process of designing robots or interactive software (Alborzi et al. 2000; Druin 1999; Montemayor, Druin & Hendler 2000). However, collaborative design, or even just talking to the users as recommended by Nielsen (1993), is not feasible in the case of children with autism who are by definition not socially oriented. In addition children with 'lower-functioning' autism may have little or no productive language.

Similarly, many techniques for involving users in software evaluation have high social mediation. Testing software with real users is recommended by Nielsen (1993, page 165). He commends 'thinking aloud' protocols as the '*single most valuable usability engineering method*' (1993, page 195). However he does note that users find it difficult, which can impact results, and that it is hard to use with children. Clearly this is even more problematic with children with autism who may have very few words. Nielsen (1993) also describes constructive interaction, sometimes called co-discovery learning, in which two people use a system together. This encourages natural discussion between the users which can form a basis for later review and evaluation. While co-discovery learning using a software game such as TouchStory might, in some cases, form a useful vehicle for *eliciting social interaction* between children with autism, the technique is not an appropriate means of informing software design and development in the case of autism.

1.3.3 Ethics and Ethos

The formal requirements for ethics approval and police clearance to work with young people were adhered to in this work. This section is concerned with the stance taken in addition to formal approval, in particular with regard to the terminology used, the duty of care to the participants, the purpose of the work, and the question of whether people with autism require 'acceptance' rather than 'assistance'.

Notes on terminology: In this thesis the term 'children with autism' is the preferred term; the term 'autistic children', formerly seen as 'labelling', is now seen as acceptable and is used by some authors, however it is avoided here. The disorder is referred to in this thesis as 'autism' or 'autistic spectrum disorder', which is sometimes abbreviated to ASD in the referenced literature; the term 'autism spectrum condition' which is currently preferred by some is not adopted here. In this thesis, where it is necessary to use a general personal pronoun the unspecified person is referred to as 'she'. In the case of an unspecified child with autism, which is heavily male dominated, the use of 'she' may mislead the reader. Peter Hobson adopts the use of 'he' for this reason (Hobson 2002). However the current author is concerned to remind the reader that autism is not only diagnosed in boys and so the more cumbersome 'he or she' is used. Specific people are referred to according to their gender; in particular girl participants are referred to as 'she', boy participants as 'he'.

The duty of care: Nielsen says, with respect to usability testing with adults in the workplace, '*tests should be conducted with deep respect for users' emotions and well being*' (1993, page 181). There may be pressure to perform even when told the purpose is to test the system not the user. The participant may feel inadequate or stupid, and knowing she is being observed makes this worse. While children with autism are not adults in the workplace, they may be more used to being observed, and they may have little concern for the opinion of others, nevertheless it would be foolhardy to disregard this advice, especially as it is known that children with autism find failure particularly debilitating (Jordan & Powell 1995). The child's time is treated with respect; the aim being to provide an enjoyable and engaging game, which at least does no harm, and which may be beneficial. Thus participants were not obliged to play the TouchStory game. In fact this is not only an issue of ethics and ethos but also of the actual research questions to be answered as the interest is in ecologically valid environments. A final concern is what happens when trials are at an end and the opportunity to play the game ends. It was not appropriate to leave TouchStory with the participating schools, even in the final version reported here, TouchStory is not ‘plug and play’, rather it is a prototype which requires a degree of ‘setting up’. However, care was taken to reward the participants appropriately, with praise and in one school with certificates, to signal the end of the longitudinal studies well in advance, and to bid goodbye appropriately.

The purpose of the work: With regard to the purpose of the work, the stance of the Aurora project (which is a long term on-going umbrella project) is to provide assistance; not to devise a cure for autism, or indeed to devise a therapy. Neither is it the intention that caring adults be replaced by the computer, rather the computer is seen as a tool to be used by such an adult.

Acceptance or assistance? Last the question is asked; do children with autism need any special assistance? Is not their way of learning and being as valid as any other? Is not the problem with society rather than with them? Certainly there are websites promoting such views. Conversely, when Ros Blackburn, a highly articulate adult with autism, was asked whether she was content with her lot in life, she responded that if there was a cure for autism she would sign up tomorrow (Blackburn 2008). The stance taken in this thesis is that people with autism do face additional difficulties, and that to research into ways of helping them overcome or avoid those difficulties is morally sound, so long as the procedures used are ethically sound. Individuals (or their parents, or those acting *in loco parentis*) may choose to accept such assistance or not. These issues are discussed by (Dautenhahn & Werry 2004) in which they say ‘*Empowering people with autism allowing them to make their own choices on whether or not to link with the world of non-autistic people poses many challenges.*’ One such challenge is to ‘*find ways to empower them, for example by using computer and robotic technology, so that they have a choice of whether and to what extent they want to connect with other people.*’

That the consequences of autism may be severe for the individual is not in doubt, as shown by this quotation taken from the National Autistic Society web page. *‘People with autism or Asperger’s syndrome are particularly vulnerable to secondary mental health problems including anxiety and depression, particularly in late adolescence and early adult life. However, problems with communicating feelings and impairment of non-verbal expression can mean that mental illnesses in people with autistic spectrum disorders are often well developed before they are recognized…, with possible consequences such as total withdrawal, obsessive behaviour, aggression and threatened, attempted or actual suicide.*

Any suicide prevention strategy for people with autistic spectrum disorders must focus on the promotion of mental well-being rather than seeking simply to restrict potentially suicidal behaviour.' (NAS 2008a).

1.4 Overview of thesis structure

The exploratory nature of this thesis is reflected in the thesis structure. The broad hypothesis (Hypothesis H0) presented in this chapter in section 1.3, is refined iteratively and research questions are elaborated as the thesis develops.

Chapter 1 provides an introduction to the thesis.

Chapter 2 presents material concerning narrative, autism, engagement and learning which motivate and are later relied upon in this thesis. The current work is set in its context by reviews of active research in the domains of assistive technology in the case of autism and narrative in the context of learning. Note that other material, which is relied upon but which is not of fundamental importance to the thesis, is introduced locally where it is needed.

Chapter 3 explains the *proto-narrative* and *t-story* concepts developed in this thesis and their underlying basis in narrative theory. A means of adapting to the needs of individual learners facilitated by the proto-narrative approach is developed. The research questions raised by the proto-narrative approach are posed, and a design framework is presented.

Chapter 4 is concerned with the design and development of the interactive software system called *TouchStory*, which presents proto-narratives. The development of TouchStory followed an iterative elaboration cycle interleaving development with long-term trials, the development is presented as a whole in this chapter. The research questions raised by the design and development of TouchStory are presented.

Chapter 5 gives an overview of the three trials used in the study, of the two schools involved in the study, and of artefacts and issues (such as methodological issues) which are common to all three trials.

Chapter 6 presents the first trial which was concerned with the efficacy of a computer based approach. That is, it addresses the research questions: would children with autism be able to use such a system? would children with autism be engaged, and enjoy using the system as intended (rather than for some other purpose)? and, would a computer-based presentation have any adverse impact when compared with a similar activity in the real world?

Chapter 7 presents the second trial, an extended study of 12 visits with 12 participants. Proto-narratives were introduced in this trial and adaptation by means of an adaptive formula employed and evaluated. The main focus of the chapter is on the following research questions: do children with autism, as individuals, not as a population, find some components of narrative more difficult than others? and, can a system such as TouchStory reflect individual abilities with respect to components of narrative and thus address individual learning needs, given that an ordering of difficulty is not known *a priori* for any individual child, and may differ among children?

Chapter 8 presents the third trial. This was a longer extended study of 20 visits with 6 participants, in which a revised adaptive formula was employed. The main focus is on the effect of the revised adaptive formula in the context of the following research question: would children with autism *learn* from using such a system? in particular does learning, if any, transfer to other related tasks or indeed generalise to the real world bringing about improved skill in the comprehension and construction of the fully developed narratives encountered in everyday life?

Chapter 9 summarises the discussion of results of the three trials presented in the foregoing chapters, and presents a discussion of the three trials as one study. The limitations of the work are described and discussed, as are the lessons learned. Guidelines for future researchers are presented.

Chapter 10 concludes the thesis, explaining the original contribution to knowledge and outlining further work.

1.5 Contribution to knowledge

The unique aspects of this work are the proto-narrative approach to narrative comprehension and the consequent possibilities for adaptation to the needs and abilities of individual participants, together with the development and evaluation over several long-term trials of an interactive system which presents proto-narratives designed for children with autism.

It was found that participants, as individuals, did find some proto-narrative categories more difficult than others. The results obtained strongly suggest that the adaptive formula which was developed did identify challenging (rather than impossibly difficult) proto-narrative categories for individual participants, and that some participants improved in the proto-narrative categories targeted by the adaptive formula. It is important to note that the adaptation did *not* aim to present participants with more difficult scenarios in areas where he or she demonstrated mastery at the current level. This was not the intention, and would not be possible as no ordering of difficulty is known. Rather, the aim was to present the participant with more examples from proto-narrative categories which he or she needed to practice, while continuing to present sufficient examples from proto-narrative categories already mastered to provide an enjoyable and engaging game. That is, to present gradually increasing practice with difficult proto-narrative categories embedded within a successful experience. This was made feasible by using a computer based approach. The iterative strategy, interleaving prototype development with several long-term trials, was shown to effectively involve children with autism in the design process. As expected most participants enjoyed the computer based approach. Enjoyment may be a particularly significant feature of the 'potential to learn' for a child with autism who may well find the social aspects of conventional school learning disturbing and even frightening.

The thesis makes a contribution in the fields of assistive technology and inclusive design, software development and human-computer interaction, and computational adaptation. A conceptual contribution was made by the introduction of proto-narrative categories as a means to enhance understanding of narrative structure. The work done during this study led to a number of publications, the details of which are listed in Appendix B.

2. CHAPTER 2: RATIONALE AND BACKGROUND

2.1 Preamble

This chapter presents the rationale for building an interactive software system specifically for children with autism, which seeks to improve the narrative skills of *individual* children by isolating the components of narrative and varying them independently. The following topics are introduced in the chapter: first, what narrative is, how it is understood, and its importance to social interaction; second, what autism is and the relationship between autism and narrative; third, the characteristics of learning environments, especially for children with autism. These are all relied on in the work that follows. Also included in the chapter is an overview of research in areas of 'autism and assistive technology' and 'education and narrative' which sets the current work in the context of the variety of active research in these areas. In any thesis it is necessary to actively select from the available literature, in particular in a thesis such as this one which draws from many disciplines, it is neither feasible nor appropriate to cover the whole corpus of literature from each discipline. The approach taken to selecting literature for inclusion in this thesis was to focus on those books, papers or talks which directly influenced the thinking of the current author, and then to situate that literature in its broader context.

2.2 Narrative

What is narrative? This is not as easy a question as might at first be thought. Indeed, Bruner (2002, page 3) said '*our intuitions about how to make a story or how to get the point of one are so implicit, so inaccessible to us, that we stumble when we try to explain … what makes something a story rather than, say, an argument or a recipe'*. It is not then surprising that there is diverse opinion on what is and is not a narrative. At its most straightforward a narrative is a *presentation* of a *story* (Porter Abbott 2002). The distinction is as follows; if a story is told several times, the presentation might vary from telling to telling, but the story remains the same, of course the story might be subtly reinvented at each telling, but basically the Cinderella story, say, remains the Cinderella story, despite varying presentations (Porter Abbott 2002). This leaves the questions 'what is a story?' and 'what is involved in presenting a story?'

A *story* may be defined as *'a sequence of events involving entities'* which is bound by the laws of time (Porter Abbott 2002, page 195). That is, the sequence follows and is temporally constrained by the order in which the events occurred (or were imagined to occur). Bruner proposed a format for a '*story worth telling*' (Bruner 1986; 2002; Dautenhahn 2002), in which the sequence of events involves purposeful characters and the pattern of events comprises:

- a *steady state* which establishes a world view,
- a *precipitating event* which is some break in the steady state, a challenge unexpected by the protagonists, not necessarily by the audience,
- a *restoration* in which the precipitating event is resolved and some steady state reached,
- a *coda* which signals that the narrative is at an end.

The presentation of a story (also known as narrative discourse), whether it is presented to others or to ourselves, involves selecting and editing, summarising, perspective taking and meaning making. The sequence of events in the narrative discourse is under no temporal constraint; the storyteller is free to introduce events in any order provided the narrative 'hangs together'. To present a sequence of events as a narrative, the storyteller must fit the events into a recognised pattern or genre; Schank uses the term 'gist' (Schank 1990). This determines the 'type' of story told. Thus, a presentation of events may be permissible in one genre but not in another; a reader of a detective novel may feel cheated by events which would be enjoyable if she was reading magical realism.

Nehaniv describes three ways in which an agent, possibly human, can relate to narrative: it can have a narrative (that is have an internal representation of the story, its gist and genre); it can express a narrative (be a storyteller), and it can recognise a narrative (Nehaniv 1999). Receiving a narrative, for example listening to a story-presentation, is an act of creative construction; in general the listener has no direct access to the story itself, which is held internally by the storyteller. The listener has access to the narrative only, that is, to the story as presented. From this, and her world knowledge, the listener must construct her own internal story. This process of narrative comprehension is described further in the section below.

2.2.1 Theories of narrative structure and comprehension

Narrative Comprehension: Narrative may be presented through many media (through the spoken word, mime, pictures, the written word etc.). To avoid medium-specific terms (listener, viewer, reader) the somewhat cumbersome word 'comprehender' is used in this section, as Zwaan does in (1999). There are a number of theories of narrative comprehension, but it is clear that each comprehender actively constructs an internal representation of the narrative, called by some authors a *mental model* and by others a *situation model*. The constructionist theory, which arose in the discipline of discourse psychology in the context of understanding written texts, predicts that each comprehender will make inferences which establish both local and global *coherence*, and *explain* events and motivations (Graesser & Wienner-Hastings 1999; Graesser, Singer & Trabasso 1994). Take for example 'The lion roared. The child cried.' The constructionist theory predicts that a comprehender will make inferences to establish global coherence (the child cried *because* the lion roared), and would use explanation based reasoning to establish the validity of this causal chain (the child was startled by the lion, the child was afraid of lions, etc.). Zwaan (1999) pointed out that to build a situation model the comprehender must keep track, not only of such causal relations but also of several other aspects of the unfolding narrative. He proposed the event indexing model and suggested five dimensions of narrative comprehension, these being; the protagonists, the space in which events unfold, time, motivation and causation. Zwaan's model was primarily concerned with the way the comprehender makes links between events in the narrative. He suggested that the events themselves would be understood in terms of pre-existing scripts, as proposed by Schank and Abelson (1977), augmented by specific event related experiential or semantic knowledge. For example, a script dealing with the events to be expected in a restaurant would be augmented differently in the case of an ice-cream parlour from in the case of a fine-dining restaurant.

As each comprehender must actively construct her own internal representation of the story, gaps in the narrative (and there always will be gaps, things left unsaid) must be filled. Being able to fill such gaps from more general scripts is an integral part of story comprehension (Schank 1990). Such narrative gaps are visually apparent in the case of those narratives presented through the medium of comics. As Scott McCloud says (1993, page 65) comics is 'a medium where the audience is a willing and conscious collaborator' in constructing and attributing meaning to the gutter, that is the gap, the white paper, between adjacent pictures. Thus he also takes a constructionist view. This view is important to this thesis and is returned to in section 3.4.

2.2.2 The central role of narrative in human social interaction

The purpose of this section is to explain the importance of narrative in constructing and conveying social meaning, particularly among human beings. As previously mentioned in Chapter 1 a central tenet of this thesis is that narrative is fundamental to the construction of social meaning. This is grounded in the work of Bruner (1986; 1990), who saw narrative as crucial to making and conveying social meaning, and in attributing meaning to our own lives, not as a *post hoc* rationalization, but rather as an ongoing process. Bruner, Linde, Polkinghorne (Bruner 1986; Linde 1993; Polkinghorne 1988) and others were concerned with the role of narrative in the creation of social meaning in a human context; Dautenhahn et al. (2000) extended this context to animals and machines such as social agents or robots.

By fitting events into a narrative pattern humans construct and inhabit a meaningful, consistent and predictable world (Bruner 1986; 1990; 1991; 2002; Linde 1993; Polkinghorne 1988; Schank 1990). 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 (Bruner 2002; Porter Abbott 2002; Schank 1990). Porter Abbott expressed it so, '*Bringing a collection of events into narrative coherence can be described as a way of normalizing or naturalising those events. It renders them plausible, allowing one to see how they all "belong"*'(Porter Abbott 2002, page 40). Bruner, referring to the normalizing power of narrative when events go awry, said, '*our plans usually work out quite quietly and well. But it is our narrative gift that gives us the power to make sense of things when they don't'* (Bruner 2002, page 28). Schank (1990) considered that stories are based on particularly interesting prior experiences, ones which we can learn from, and further, that narrative provides a means to structure a series of events into a single unit which can be remembered more easily. Narrative gives not only a means of understanding and remembering but also a means of forgetting. In Schank's view a sequence of events is recognised as being similar to the gist or bare bones of some already known story. This gives the means to understand and remember; but there is no way of remembering events or details which do not fit the pattern, so they are forgotten (Schank 1990). Narrative thus gives a way, possibly flawed, of distinguishing what is important and memorable from what is not, freeing the human to attend to the important things.

Through narrative a sense of self is developed enabling the individual to understand the behaviours of others (people or other agents attributed with intent), and to respond in ways seen as meaningful and consistent. It allows us to bring coherence to our own lives; by casting life events as 'life stories', which may be told, rehearsed and revised, a human is able to give coherent accounts of her life, and how she got to be where she is (Linde 1993). Polkinghorne took a similar view and wrote, '*We achieve our personal identities and self-concept through the use of narrative configuration, and make our existence into a whole by understanding it as an expression of a single unfolding and developing story'* (1988, page 150). He went on to say that, as we do not know how things will turn out, we have to continually reinvent this personal story as new life events unfold. Thus a self is not a static entity but is under constant reconstruction.

Returning to the communicative role of narrative, both Dautenhahn and Schank point out that, while narrative is often seen as a (high) art form, it primarily serves an every-day communicative function (Dautenhahn 2002; Schank 1990). Dautenhahn developed the narrative intelligence hypothesis, which suggests that narrative evolved within, indeed co-evolved with, increasingly complex societies (Dautenhahn 2002; 2003). Narrative provides a way for humans to form or fit into social groups by providing a structure in which to understand, remember and share local tacit social knowledge (Linde 2001). For example knowledge of what is appropriate behaviour in a given social situation, say, in the classroom at a particular school. While schools and other organisations may have rules, tacit social knowledge in general is not readily expressed as rules, nor is it readily quantifiable. However, such knowledge, Linde says, *'is not unspeakable: it is commonly and easily conveyed by narrative, although narrative exemplifies rather than exhaustively describes such knowledge'* (Linde 2001, page 161).

2.3 Autism as a deficit in social interaction

To come to a general understanding of autism the current author consulted not only recognised authorities such as Frith (1989) and Wing (1996) but also autobiographical and biographical accounts such (Grandin 1995; Sacks 1996), and oral autobiographical accounts (Blackburn 2003; 2008). Autism is a lifelong pervasive developmental disorder affecting social ability. Although people with autism form a diverse group (which is addressed in the current work), they all exhibit impaired social interaction and social communication and have a limited range of imaginative activities, sometimes referred to as the 'triad of impairments' (Frith 1989; Powell 1999; Wing 1996). Additionally it is common to find particular sensitivities (Bogdashina 2003), repetitive behaviour patterns, and resistance to change in routine (NAS 2008a). People with autism have great difficulty making sense of the world, in particular the social world; that is not to imply that there is no meaning to the lives of people with autism, rather that socially constructed meaning is difficult, and the more socially constructed the meaning, the greater the difficulty. Autobiographical accounts such as (Grandin 1995) show that people with autism who do live successfully in the, to them, bizarre world of non-autistic people do so at least in part by learning explicit rules for social situations. Recall that such information is not easily turned into rules; it is normally conveyed by example and narrative. Thus such rules are never universally applicable; there will always be instances when they are not appropriate. Ros Blackburn, an entertaining speaker, amusingly describes her serious experiences as an adult with autism, and the social misunderstandings which arise when 'the rules' are misunderstood, or the 'wrong rule' is applied (Blackburn 2003; 2008).

There is no definitive physiological test for autism, rather it is diagnosed using diagnostic criteria. A commonly used instrument is the Diagnostic and Statistical Manual of Mental Disorders Criteria 299.00 (American Psychiatric Association 1995), referred to as DSM-IV. This requires the following for a diagnosis of autism:

1. Qualitative impairment in social interaction, as manifest by at least two items from a list of such.
2. Qualitative impairments in communication as manifest by at least one item from a list of such.
3. Restricted repetitive and stereotyped patterns of behaviour, interests and activities, as manifest by at least one item from a list of such.
4. Delays or abnormal functioning in at least one area with onset prior to the age of 3
    a. social interaction,
    b. language as used in social communication,
    c. symbolic or imaginative play.
5. The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder.

The Childhood Autism Rating Scale known as CARS (Schopler et al. 1980) is used by some, including one of the schools involved in this study, in preference to DSM-IV. With the CARS instrument the child is rated on a scale of 1 to 4 in each of 15 areas which include:

relating to people; body use; adaptation to change; listening, response and verbal communication. A score of 30 or above out of 60 indicates autism.

2.4 Autism and narrative

Autism and Narrative: One may ask whether people with autism, who necessarily have difficulty finding socially constructed meaning, also experience difficulties with narrative. Temple Grandin, in conversation with Oliver Sacks, comments on the difficulties she experiences, as an adult, in following narrative. She attributes this to 'sequencing difficulties' (Sacks 1996). Indeed, as noted in Chapter 1, in the case of children with autism it has been shown that they have some specific difficulties with narrative. Studies using narrative pictures showed that references to causality, affect (aside: the word affect refers to the emotions or moods of the characters), and motivation may be missing or inappropriate (Capps, Losh & Thurber 2000; Tager-Flushberg & Sullivan 1995). 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, Happé & Frith 2000). The precise nature of these difficulties is an open question, and is the subject of current research (Diehl, Bennetto & Carter Young 2006). This narrative impairment is often attributed to a deficit in a theory of mind (Baron-Cohen 1995), that is, to an impairment in understanding that different minds have different knowledge and motivations; that what is known by one person is not necessarily known by another. However, a number of researchers see narrative as fundamental, guiding perception itself as well as the creation and communication of meaning in social interaction and thus they view the narrative deficit seen in children with autism as a cause rather than a symptom of their social and temporal difficulties (Bruner & Feldman 1993; Dautenhahn 2002; Hutto 2003). It is worth reiterating that the stance taken in this thesis is that evidence has been shown for a narrative deficit in autism, and the purpose of this study is to find ways to assist children with autism to improve their narrative skills; there was no intention of providing further data on the differences in narrative skills among populations of children with and without autism.

2.5 Autism and learning

In the context of this thesis 'learning' is interpreted as the act of gaining knowledge, skills or attitudes and is deemed to be observable as a relatively permanent change in behaviour that is a direct result of experience. That experience may or may not be engineered by others, that is it may, or not, be 'taught', hence learning is not necessarily dependent on teaching.

In autism there are complex difficulties with learning that stem from a seeming lack of the need to makes sense of the world in a way that is a feature of non-autistic thinking, as previously discussed, and which underpins non-autistic learning. Combined with their fundamental difficulties in 'making sense', individuals with autism have difficulties within the social domain that significantly weaken their communicative abilities in terms of, for example, intention, imitation and the development of narrative. These fundamental difficulties with communication mean that, in autism, any learning within a social context inevitably starts from a disadvantaged position. Of course, conventional education is set within a social context (or more properly, within ever changing social contexts) and the power of social factors within any such education is therefore pervasive.

While autism is primarily a social deficit and children with autism vary greatly, there are some characteristics common in autism which impact educational approaches. Such characteristics are presented from diverse research sources in section 2.5.1. Guidelines on the provision of learning environments (computer based or otherwise) for children with autism are presented in section 2.5.2.

2.5.1 Characteristics common in autism

When designing environments for children with autism there are considerations in addition to those necessary for typically developing children, as illustrated in the list below:

- Children with autism are likely to prefer predictable, structured and controlled procedures and environments and, possibly consequently, they like inanimate objects, machines and computers (Murray & Lesser 1999).
- Children with autism are generally thought to be highly visual thinkers and learners (Francis 2005; Grandin 1995).
- Children with autism might have little apparent understanding of joint attention or of shared points of reference such as references made to remote objects by pointing (Jordan & Powell 1995). Children with autism are not incapable of such behaviours, for example, Robins et al. (2004) have shown that such behaviour can be *elicited* from some children with autism through the medium of an interactive robot. However an interface designer

should not *rely* on a child with autism understanding a reference made to an object by pointing at it.

- Children with autism may not be able to use a standard keyboard or mouse (NAS 2008c).
- Children with autism may be highly sensitive to noise, finding intolerable noise which is barely perceptible or unremarkable to others (Bogdashina 2003).
- Children with autism generally enjoy repetition and may engage in repetitive activity to the detriment of other activities (Jordan 1997).
- Children with autism have a tendency to focus on particular details, that is, they tend to employ local rather than global integration (Happé 1997). A preference for local integration was shown in children with autism in the case of voluntary selective attention, that is, when the participants are not given guidance on what to attend to. Again, children with autism are not incapable of focussing on the global picture rather than on detailed aspects; Plaisted, Swettenham and Rees (1999) showed that children with autism could attend to the whole picture rather than it's parts if they were overtly primed to attend to the global level. However, interface designers should be aware that children with autism may focus on seemingly irrelevant detail.
- Children with autism may find failure very debilitating, as they might be employing strategies which worked in the past (Jordan & Powell 1995).

These characteristics, while not part of the diagnostic criteria of autism *per se,* are commonly found in children with autism. This list is drawn, not from one particular school of thought, but from a variety of research sources, with the intention of informing the initial design of TouchStory from a broad perspective. This list is returned to later in this thesis in the context of the design of TouchStory.

2.5.2 Educational environments and approaches for children with autism

This section begins with a consideration of guidelines on the provision of learning environments (computer based or otherwise) for children with autism. It then turns to consideration of overarching issues and generic challenges in the design of educational environments, in particular educational software.

The guidelines on the provision of learning environments for children with autism draw, in particular, on the work of Jordan and Powell, who publish widely, both together and separately, on the subjects of understanding children with autism (Jordan 1999; Jordan &

Jones 1999; Jordan 2005; Powell 1999), teaching children with autism (Jordan & Powell 1990; Jordan & Powell 1995; Jordan 1997; 2007; Powell 2000; Powell & Jordan 1997), and models of inclusion for children with autism (Jordan & Powell 1990; Jordan 2008). Powell (2000) argued that, in the case of autism, '*the very nature of teaching and learning needs a special kind of scrutiny'* (Powell 2000, page 1). The issue hinges on socially constructed meaning; that is meaning attached to objects or procedures through social interaction and consensus, over and above that which is perceptually available. Powell's example is that of meat-eating; a child may attach meaning to this practice, not through explicit teaching, but rather through observing a parent's demeanour and enjoyment or avoidance of the activity. Such meaning-making is impaired in children with autism. While a child with autism may attach meaning to objects or procedures, that meaning may be highly idiosyncratic rather than shared, and rigid, having meaning in only one context. This contrasts with the case of typically developing children, who readily attach such socially constructed meanings, and for whom not only is education highly socially mediated, but learning itself may be become meaningful through social processes, see for example (du Boulay & Luckin 1999).

In providing a learning environment for children with autism Jordan and Powell advised that the environment, including teachers, should be as dependable and predictable as possible, with any required unpredictability carefully introduced in a controlled way (Jordan & Powell 1995). They advised that learning activities for children with autism should be challenging, but children should not be penalised for mistakes as they may be using strategies which worked in the past, and the fact that they do not work in the current situation can be very debilitating. Feedback on failure should be non-threatening and must be accompanied by clear cues to an alternative way forward. Lastly they advised that children should be allowed time to enjoy their mastery of a skill before moving on (Jordan & Powell 1995). Children with autism are widely held to be visual learners and thinkers (Grandin 1995). Indeed, in a critique of current interventions in autism Francis concluded that, based on current findings the most effective interventions are structured teaching based on visual cues (Francis 2005).

Consideration now turns to overarching issues and generic challenges in the design of educational environments, in particular educational software. This draws on the research of du Boulay who through diverse studies investigates the potential of intelligent tutoring systems, in particular by modelling aspects of both the learner and the teacher. Du Boulay and Luckin (1999) provided discussion of some approaches to computer mediated learning, in particular raising issues of what it means for a computer-mediated system to be effective, and how such systems should be designed and evaluated. Del Saldato and du Boulay (1995) addressed the issue of modelling the learner's motivational state, and took *effort*, rather than, say, *performance* to be a reliable measure of motivation. Rebolledo-Mendez, duBoulay and Luckin (2006) provided an empirical evaluation of an approach which modelled, and then adapted to, the learner's motivational state during interaction, as evidenced by the learner's persistence in the face of errors, independence from system based help, and the degree of challenge-seeking exhibited. This work follows (Luckin & du Boulay 1999), which developed and evaluated a Vygotskian design framework in which to model the learner, in order to determine at what points in a learning session the system can most beneficially provide help to the learner, and what sort of help should be offered. Vygotsky and his work are returned to in section 2.6.2. With regard to modelling the teacher, Du Boulay and Luckin (2001) discuss this issue; they asked whether it is appropriate for an intelligent learning environment to reflect the strategies a human teacher might adopt, and speculated on the possibility of systems with personality.

Du Boulay (2000) discussed a set of generic challenges faced by researchers involved in the creation of educational software and he raised a number of questions. This work was selected as, although presented in the context of typically developing (or developed) learners the questions are posed at a generic level making the questions relevant to children with autism, although answers to, or discussion of, the questions may differ. The following generic questions posed by du Boulay (2000) are particularly relevant to this study:

- *How can we engage and motivate [students] so they are willing to attempt to learn?*
- *How can we detect what the goals of the student are (if any)?*
- *How to maintain focus and coherence in the interaction?*
- *How to make the teacher's intentions to the learner clear?*
- *What makes an environment educationally rich?*
- *How does one choose what assistance might be helpful*?

These are all difficult questions whoever the learner, but doubly so in the case of autism. These questions are returned to in Chapter 4 which describes the design of TouchStory, and again in Chapter 8 in the discussion of trial 3.

2.6 Play, fun and engagement in learning and narrative

A concern in the design of TouchStory was that not only should it provide an environment which was suitable for children with autism, but also that the participant would find interaction with TouchStory an enjoyable experience. The motivation for this was first that a playful context and enjoyment enhance learning (Tokoro & Steels 2003), and second that time spent in on an enjoyable activity is valuable of itself in the case of children with autism. Play and enjoyment are central to the Aurora approach and can be seen in studies, both within the Aurora project and elsewhere, using a variety of robots with children with autism (Dautenhahn & Werry 2004; François, Polani & Dautenhahn 2008; Kozima, Nakagawa & Yasuda 2005; Robins et al. 2004)

However, authors agree that play is difficult to define, encompassing diverse and complex behaviours (Bateson 2005; Jordan & Libby 1997). Of particular relevance here is that through play typically developing children build up a concept of narrative structure, for example, through games such as peek-a-boo (Bruner & Feldman 1993). Play provides a way of actively acquiring new skills and knowledge which will later be relied upon for serious purposes (Bateson 2005). It thus provides a safe environment in which to try out new skills (Boucher 1999) including social skills.

It cannot be assumed that concepts of play which apply to typically developing children also apply to children with autism. Much work has been done on the play abilities of children with autism, mostly in the area of 'pretend' play. Autism may affect all forms of play, but in particular spontaneous symbolic play is rarely seen (Jordan & Libby 1997; NAS 2008b). Play is not *absent* in children with autism, for example the Aurora project has demonstrated apparently social and playful behaviours (imitation, turn-taking etc.) elicited by interaction with robots (Dautenhahn & Werry 2004; Robins et al. 2004). However spontaneous play, where it exists, is generally highly predictable (NAS 2008a) rather than social, imaginative, 'playground play'. The current study is not primarily concerned with directly teaching or eliciting playful or social behaviours; rather, it is primarily concerned with finding other means through which the child may build a concept of narrative structure (and thus ultimately find the social world less bewildering). Therefore the aim is not to create an environment rich in 'playful play', but rather an enjoyable, engaging and rewarding experience.

How is such a rewarding and engaging experience to be provided in a learning environment for children with autism, specifically in one which addresses simple picture narratives or proto-narratives? Three schools of thought providing insight on this issue are introduced in the following sections. Section 2.6.1 is concerned with Csikszentmihalyi's concept of 'flow' (Csikszentmihalyi 2000; Steels 2004), which occurs when there is a good balance of skill and challenge. Flow is important because it is an enjoyable experience, '*the person who experiences the enjoyment seeks it again, i.e. it becomes self-motivating. Moreover due to the high concentration and strong self-motivation learning takes place very fast'* (Steels 2004, page 140). Section 2.6.2 is concerned with the work of Vygotsky, in particular on his notion of a *zone of proximal development* (Vygotsky 1978). This again is concerned with challenges at the leading edge of an individual's skill level, but in this case, crucially, the challenge is socially mediated by a more capable adult or peer. That is, the zone of proximal development contains those challenges which a child cannot meet alone, but *can* with the help of a more capable other. Section 2.6.3, which is based on the work of Boorstin (1990), addresses the last of these three areas of insight and is concerned with enjoyment of, and engagement in, narratives.

2.6.1 Concepts of flow and engagement

This section introduces Csikszentmihalyi's concept of 'flow' which occurs when an individual is highly engaged (Csikszentmihalyi 2000), and Steels' application of these ideas to learning environments (Steels 2004). Csikszentmihalyi describes '*the flow experience, which … is the crucial component of enjoyment*' (Csikszentmihalyi 2000, page 11). This is the decrease in self-consciousness and time awareness, accompanied by feelings of control and competency, and the pleasurable state of high involvement, which occur when a skilled individual engages in a challenging activity. He also describes 'microflow' in everyday activities such as doodling, chatting etc.; '*microflow activities may be as intrinsically rewarding as deep-flow activities, depending on a person's life situation*' (Csikszentmihalyi 2000, page 141). He likens microflow to John Dewey's concept of a 'completed experience', a completed and satisfactory experience, which, because it is complete, brings feelings of consummation and self sufficiency. In the context of education Csikszentmihalyi asserts that studies of flow indicate that any topic can be made enjoyable, but stresses that this is not achieved by trivialising the topic. '*In theory, it is simple enough to make any learning enjoyable: find out what the students skill's are and what their level is, …, and then devise* *limited but gradually increasing opportunities for the expression of those skills. The learning will then become intrinsically motivated*' (page 205). Notice that limited but gradually increasing opportunities to express skills fit well with the preference of children with autism for predictable environments, and can accommodate their tendency to local integration rather than global integration.

Luc Steels (2004) appeals to the concept of flow and applies this to design principles for learning environments thus: for flow to occur, '*.....the activity itself must be challenging – otherwise there is no feeling of satisfaction after difficulties have been surmounted. Moreover there must be a steady progression in the nature and particularly the level of the challenge*.' (Steels 2004, page 140). To provide this in a learning environment *'A learner must be able to feel some control of the challenge level, but at the same time the environment is crucial in generating new opportunities and providing structure to the learning experience*.' (Steels 2004, page 142). These issues are revisited in Chapter 4 which is concerned with the design of TouchStory.

2.6.2 Vygotsky's zone of proximal development

The notion of a skilled individual learning through a challenging activity is inherent in Vygotsky's concept of the zone of proximal development (Vygotsky 1978). However, the zone of proximal development is a social concept, it encompasses those tasks which a child cannot do alone, but can do in collaboration with a more capable other; these are the things which the child can actively learn. Vygotsky stresses the importance of concentrating on what a child can do *with help*; otherwise nascent abilities never come to fruition. This is exemplified in the following quotations (which are in translation):

- [The zone of proximal development is] '*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*' (Vygotsky 1978, page 86).
- '*the zone of proximal development defines those functions that have not yet matured but are in the process of maturation'* (Vygotsky 1978, page 86).
- '*the notion of a proximal development enables us to propound a new formula, namely that the only "good learning" is that which is in advance of development*' (Vygotsky 1978, page 89).

Vygotsky illustrates the importance of teaching in the zone of proximal development with an example of the teaching of 'mentally retarded' children. In summary: studies had revealed such children were not good at abstract thinking, teaching was organised to play to their strengths, and so was based on very concrete 'look and do' methods. This, says Vygotsky, reinforced the children's handicaps, '*accustoming the children exclusively to concrete thinking and suppressing the rudiments of any abstract thought that such children still have*' (1978, page 89). Precisely because the children will not achieve abstract thought unaided, the school should make every effort to develop it.

Bruner, who has been mentioned several times as being a seminal influence on this thesis, is a great admirer of Vygotsky, of whom he wrote '*Vygotsky was plainly a genius'* (1986, page 72). In following Vygotsky's work, Bruner et al. carried out experiments on tutoring children in which the task was to build a pyramid from wooden blocks (Wood, Bruner & Ross 1976, cited in Bruner 1986). It was observed that the tutor turned the task into play, controlled the focus of attention, demonstrated the task was possible, set things up so the child could recognise a solution even though the child could not achieve it alone, and segmented the task for the child. She did the things the child could not do, she ensured that the child did do things with her that he clearly could not do alone, and, as the child gained skill she relinquished control. That is, she situated the tutoring in the child's zone of proximal development.

Vygotsky's arguments motivate assistive technologies for children with autism which identify zones of proximal development for individual participants, and give a focus for providing adaptation to individual learning needs in learning environments. In referring to the social context of the zone of proximal development Vygotsky refers specifically to collaboration with more capable *people*. He was not in a position to comment on 'collaboration' with robots or modern computer based technologies. Nevertheless, the stance taken in this thesis is that the concept of such a 'learning zone' is applicable in a robot or computer based context.

Thus in this thesis the zone of proximal development is taken to be as follows: it holds those tasks which the child cannot carry out unaided, but which she can carry out in collaboration with a more capable other, and for which she can appreciate that a desirable conclusion has been reached (for example she can recognise, or reason about, or 'see the sense in' the task outcome). In this thesis two things are assumed: 1) the guidance may be robot or computer based; 2) the agent offering the guidance (whether adult, more capable peer, robot or computer) has two jobs, which may be interleaved. The first is to identify those tasks which are in the zone of proximal development; the second is to determine the style of collaboration or guidance which is to be offered. These two jobs can be seen in the previously mentioned work of Luckin and du Boulay (1999), where the system attaches two tags to each learning node, one being a tag representing the system's belief about the learner's level of independent ability at this node, the other being the system's view of the amount of collaborative support it should offer this learner at this node.

2.6.3 Engagement in narrative

Turning to engagement in narratives, it is known that people with autism tend to prefer factual material; Temple Grandin's difficulty with narrative has already been mentioned in section 2.4. However, it is instructive to consider the ways in which a typical population engages with narrative, in particular with films (movies) as the interest is this work is not in written narratives. Boorstin describes three ways in which films engage the viewer. A film may engage the 'voyeuristic eye', which is engaged by the joy of learning and discovery. '*It is a plodding, literal view of the world – it requires a thudding sense of the reality of things, of the plausibility of actions. It can ruin the most dramatic moment with a mundane concern. … For a movie to work, the voyeur's eye must be pacified. For a movie to work brilliantly it must be entranced*' (Boorstin 1990, page 13). A film may engage the vicarious eye, that is, empathy through understanding the characters' emotions and choices. '*The vicarious eye puts our hearts in the actors body*' and '*can be profoundly moving'*, (Boorstin 1990, page 67). Last, a film may engage the visceral eye, which reacts to the audio-visual stimuli; '*the passions aroused are not lofty, they're the gut reaction of the lizard brain*', (Boorstin 1990, page 110). It is known that children with autism give bizarre causal explanations and misunderstand the motives and emotions of characters. It may be supposed that both voyeuristic and vicarious engagement are compromised in people with autism.

In this section it has been shown that Vygotsky gives a reason to make every effort to develop the voyeuristic and vicarious eye in children with autism, Csikszentmihalyi gives a strategy for achieving such engagement, and Steels gives guidelines for providing such engagement in a learning environment.

2.7 Assistive technology and the case of autism

This section covers the reasons why computer-based technology provides a comfortable environment for children with autism, a discussion of the ways in which technology may be assistive for children with autism, and a review of active areas of research into the use of robots and interactive systems with children with autism. The notion of computers as an assistive technology for children with autism is by no means new. In 1973 Colby published a rationale for the use of computers in the treatment of language difficulties in nonspeaking children with autism. His approach was to minimise adult 'interference' and to encourage exploratory play in which the child used a keyboard to control an audio visual display (Colby 1973). He reported that his approach rekindled an interest in attempting to speak in 13 out of 17 participants with autism. It is interesting that the aims of reducing unnecessary social mediation and encouraging self-directed exploratory activity are still among the aims of researchers using robots and interactive software systems with children with autism.

2.7.1 Computers as a comfortable environment for children with autism

Children with autism are generally resistant to change and prefer predictable environments. Computer systems have just such dependable and predictable qualities. Murray explains why computers suit people with autism so well (Murray 1997a), her reasons include: computer systems are rule-governed and therefore predictable and controllable; they are highly contained and therefore only one thing needs to be attended to; they offer a limited set of stimuli; and they allow for safe error making. Through these characteristics they provide a comfortable, calming experience. Her method of employment is to sit beside the child at the computer, without crowding the child, to comment positively on what is happening and help if asked, but not to intervene or divert the flow unnecessarily.

2.7.2 Assistive technology and autism

The role of assistive technology is perhaps more subtle in the case of children with autism than it is for children dealing with physical problems, the aim being to help children with autism to take part in the social world. Several approaches have been taken to providing cognitive prostheses as defined in section 1.3.1. These are categorised by the current author as follows.

First, assistive technology may enhance existing or nascent abilities, thus allowing the child to express those social skills which he or she does have, but which are overwhelmed by the complexities of human social interaction. This can be seen, for example, in the work of Robins, Dautenhahn and Dubowski (2005) who, by using a small humanoid robot, were able to elicit some social behaviours previously not noticed in their participants, such as imitation and simple co-operation.

Second, assistive technology may be used as a social prosthesis during social interaction. Moore, Cheng and Powell (2005) speculate that virtual reality may be used in such a way, allowing children with autism, *"through their avatars, to communicate more fruitfully with other people", "and thus circumvent, at least in part, their social and communication impairment"*.

Third, assistive technology may provide a task-based, on-the-spot, cognitive prosthesis which helps the user to remember or think in difficult situations. Newell et al. (2002) discuss information technology for cognitive support. While their main interest is in supporting the elderly, they also address other cognitive needs such as those found in autism. Existing paper-based techniques which are commonly used to aid recall or promote understanding may be enhanced by modern technology, an example being an electronic timetable used to help a child with autism to be confident about what was going to happen next in the school day (Murray 2003). This might help the child with autism to cope with changes in routine, a particularly challenging time being when he or she moves to a new school. Recall from section 2.3 that successful people with autism, such as Temple Grandin, may function socially by remembering rules. A function of a cognitive prosthesis might be to enhance existing abilities to 'follow the rules' and behave in ways seen as normal. Being able to behave in ways seen as 'normal', even without understanding, is profoundly important as it impacts the responses of others.

Fourth, assistive technology may assist not only in the deployment but also as a thought tool in the *production* of coping strategies such as those employed by Temple Grandin.

2.7.3 Assistive studies using robotic and computer technologies

Recently there has been growing interest in the use of interactive software and robotic systems by children with autism, particularly in a social context. Ouriel Grynszpan and his colleagues are developing software design guidelines with autistic users specifically in mind. They have a long term goal of developing software design guidelines relevant to the various subgroups of autism, their focus to date has been on teenagers diagnosed with high functioning autism (Grynszpan, Martin & Nadel 2005; 2007).

Studies using robots: A number of studies investigate the potential of robots to elicit social interaction in children with autism. The Aurora project explores the use of social robots with children with autism (Aurora 2000); robots have simpler, more limited, and more predictable behaviours than humans and have been shown to evoke social behaviour in some children with autism. Dautenhahn and Werry discuss the role of interactive environments in autism therapy, and summarises the results of trials with a particular mobile robot (Dautenhahn & Werry 2004). Robins et al. used a small humanoid doll-like robot called Robota in a longitudinal study to encourage imitation and social interaction skills (Robins et al. 2004). The robots used in both these studies had a simple appearance and a limited range of simple behaviours. Indeed Robins and Dautenhahn (2006) showed that on initial contact at least, children with autism preferred a plain appearance; this was so both in the case of Robota and in the case of a human mime artist. The theme of simplicity is seen also in the work of Kozima et al. who designed a robot called KEEPON (pronounced *key-pong*). KEEPON is a small creature-like robot resembling a yellow snowman, which can express attention (by orienting its face) and express emotion (by rocking and bobbing). The design principle behind KEEPON was to keep it as simple as possible (Kozima, Nakagawa & Yasuda 2005). Kozima et al. conducted an extended study in which children from 2 to 4 years old with developmental disorders such as autism were allowed to interact freely with KEEPON, with no experimental setting or instructions. It was found that KEEPON elicited a playful relaxed mood and spontaneous dyadic play. They found, as did Robins et al. (2005), that the robot could act as a social mediator, allowing the play to expand to triadic play (the child, the robot and an adult). It was found that each child had a different play style and unfolding of interaction. Michaud also stresses the importance of simplicity and also robustness. He has worked with a number of robots with children with autism, for example working with Duquette and Mercier on Tito (Duquette, Michaud & Mercier 2008). Tito is in appearance a simple anthropomorphic toy, somewhat more 'real world' and less stylistically simple in appearance the KEEPON. The aim of Duquette et al. (2008) was to reduce what they term 'avoidance mechanisms' such as repetitive stereotyped play and to facilitate shared attention and symbolic modes of communication. In a study under the Aurora project François et al. (2007) used an AIBO robot to engage children with autism in play. They found different play styles among participants, as did Kozima, and used self organising maps to adapt the AIBO's behaviour to the child's play style. Stanton et al. (2008) compared interactions between children with autism and an AIBO with interactions between children with autism and a mechanical toy dog. They found that their participants engaged in more social behaviours (e.g. talking, stroking) and fewer behaviours indicative of autism (e.g. rocking back and forth, flicking fingers and hands, high-pitched noises) while interacting with the AIBO than while interacting with the mechanical toy dog.

The work described above gives a typical, though not exhaustive, overview of current research into the use of robots in the case of autism. It can be seen that in all this work the main emphasis is on directly eliciting or facilitating play and social communication through the use of robots. A recurring theme is that the robots used or designed are deliberately simple in appearance and behaviour. This approach has been shown to engage not only children with autism, Tanaka et al. (2005) use a dancing robot with typically developing toddlers.

Studies using virtual environments: Virtual environments, both single user and collaborative, have been investigated in recent research as assistive technologies for children with autism. Moore et al. (2005) make a prima facie case for collaborative virtual environment technology as potentially valuable for people with autism. Such assistance may have two main goals. First, as a social prosthesis, for example, Moore et al. explored the use of simplified behaviours by means of humanoid avatars in a collaborative learning environment, his focus being on facial expressions. They discuss the possibility that children with autism may be able to achieve communication with another human being through the medium of an avatar (Moore et al. 2005; Moore, Cheng & Powell 2005). Second, virtual environments have been studied as a safe and comfortable environment in which to explore and rehearse social scenarios, allowing the participant to practice safe, appropriate and polite responses for social situations. Making friends is difficult for people with high functioning autism or Asperger's Syndrome (a sub-division of autism) who may understand what friends are but not know how to be friends. A virtual environment may give participants the opportunity to practice 'being friends' in an environment with fewer subtle social rules than are present in everyday social interactions, and as Parsons et al. (2000) suggest, at a slower pace than direct person to person interaction, giving the participant time to absorb, reflect and react. They suggest that the virtual environment gives the participant active control over social interactions, and may thereby increase confidence. Virtual reality facilitates both the enhancement of existing abilities and the development of coping strategies. The AS Interactive project (VIRART 2000) worked with several such scenarios. Their target group was older children, adolescents and adults with high functioning autism, and the scenarios involved the social situations of visiting a café, which involves choosing a seat, and the subtly different scenario of choosing a seat on a bus (Cobb et al. 2002; Kerr, Neale & Cobb 2002). This addressed, among skills already noted, the skill of waiting. Waiting is particularly difficult for children with autism. Naomi Josman et al. (2008) at the Laboratory for Innovation in Rehabilitation Technology (LIRT) have used virtual reality for a number of rehabilitative and therapeutic purposes. Recently a virtual reality scenario dealing with street crossing skills has been used with several groups, one such group being six autistic children aged between 7 and 12 years. The children were able to practice street crossing skills such as waiting for the lights to change, and looking right and left. The game has a number of levels, with faster traffic at more advanced levels. The overall aim of both the AS Interactive and LIRT scenarios is to enable and promote independence in the participants.

Cassell previously explored a suite of technologies for *story-listening systems* for playful narrative elicitation in typically developing children (Cassell 2002). One of these is Sam, a child-like, life-size language-enabled animated character. Such story listening systems rely on a number of skills found among typically developing children, their story telling and communication skills, their social skills in peer play, and their imaginative skills; skills which cannot be depended upon in children with autism (Tartaro 2006). Tartaro proposed that instead of relying on such skills, a story-listening system may assist in eliciting and developing such skills. Tartaro and Cassell proposed using Sam as an authorable virtual peer to engage high functioning children with autism in collaborative storytelling (Tartaro & Cassell 2006). Their recently published results have shown that aspects of contingent discourse (that is, conversation in which what is said relates to and is contingent upon what has just been said by a conversation partner) were more likely to occur, and more likely to improve over time, in conversations with a virtual peer than in conversations with a typically developing peer child (Tartaro & Cassell 2008). Again, simplified social interactions and the possibilities of practice and repetition can be seen to be afforded by the technology.

In contrast, rather than providing practice with social scenarios, Heerera and Vera use a virtual classroom scene to teach children with autism abstract concepts such as size (Heerera

& Vera 2005). The advantage of this approach, as seen by the current author, is that it reduces social mediation, allowing learning to take place in a simplified social world.

Researchers using robots and those using virtual reality as assistive technologies with children with autism cite the following advantages afforded by the technologies: the simplified social interactions; the possibilities of practice and repetition with gradual and controlled modification (of the behaviours of the robot, of the virtual scenario, etc.); and, in contrast, the aspects of autonomy, control and safe exploratory experience it affords the participants. Kerr et al. (2002) discuss issues of achieving a balance between the control of the learning agenda by the software, and affording the participant control over his or her own (learning) experience.

Other computer based studies. As previously mentioned, until recently there was little software written specifically for children with autism. Keay-Bright (2006) has developed embodied user interfaces in which the participant plays with reactive pictures projected onto a wall, this provides a very playful environment, free of social mediation and reliance on language, her goal being to decrease anxiety and increase creativity. Rita Jordan reports that observers have noted of participants with autism, '*their spontaneity and delight, their release of anxiety as they operate in this controllable world and, above all, their ability to engage and problem solve in ways that were not apparent outside this project*' (Jordan 2007, page 11).

Other studies addressing the educational use of interactive systems with children with autism include the following:

- The use of a multi-media system for teaching literacy and communication with children with autism (Tjus & Heinmann 2000).
- Educational games for children with autism, in which the software system adapts to the child, for example, if the child looks away the system plays a tune to re-attract attention (Sehaba, Courboulay & Estraillier 2005). A concern held by the current author about this approach is that eliciting the tune may become an end in itself, thus creating exactly the opposite effect to the one intended.
- One example of a software system used as a social mediator providing an engaging focus of attention and shared experience is a software game of noughts and crosses (Pino 2003).

Robotic and computer technologies have, then, been shown to be effective in engaging children with autism in several ways: in learning, the benefits of computer aided learning are well documented in the case of autism (Jordan 2007); in social behaviours, by facilitating or mediating social interaction; and in playful activities.

2.8 Narrative in learning and therapy

While the main interest in narrative in this thesis is its centrality to the construction, retention and sharing of coherent social meaning, the power of narrative is harnessed in many ways by educators. Stories are commonly used in the classroom as a vehicle to aid understanding, for example to enhance vocabulary or literacy, or to address difficult issues. These modes of employment assume and depend on narrative skills and understanding. Boltman (2001) provides a list of 18 referenced benefits of storytelling in the classroom including the contribution storytelling makes to a relaxed atmosphere; familiarity with events beyond personal experience; enhancing vocabulary; and developing attention, listening skills and critical thinking. It is known that children with autism have difficulty with *some aspects* of narrative. It is, then, reasonable to conjecture that enhancing the narrative skills of children with autism will not only enhance their social understanding but will also render other (socially mediated) aspects of the curriculum more accessible. Further, the constructivist stance holds narrative to be central to learning itself. Just as narrative can bring a coherence to our lives through our repeated re-construction of our life stories (Linde 1993), so it can bring coherence to a learning experience. Luckin et al. (2004) express it as the way in '*which learners discern and impose a structure on their learning experiences, making links and connections in a personally meaningful way*'. Brna (2008) gives an overview of progress and remaining challenges in narrative interactive learning environments, in which he emphasised the meaning-making role of narrative in educational contexts. It is reasonable to conjecture that an enhanced understanding of narrative may render constructivist learning more attainable for children with autism, enhancing diverse aspects of learning not only those, already suggested, which are strongly socially mediated.

Note that narrative ability is not the same as literacy (though clearly in the conventional sense literacy includes some notion of narrative ability); narrative does not depend on reading or writing, narrative may be in the oral tradition or be non-verbal (Bruner 1991), for example dance or puppetry. Oral storytelling is alive in classrooms as can be seen from, for example (The Scottish Storytelling Centre 2007). This sort of storytelling is live person-to-person storytelling, in which the basics of the story are remembered by the storyteller, these being *'the sequence of events, key phrases, images, dramatic shifts of moods and emotions*' (Bremner & Smith 2001), but the narrative is created afresh every time, personalised, depending on the storyteller and the audience. By encouraging the audience to contribute to the story, and by having a discussion time afterwards, the educational storyteller provides a fertile environment for the development of story-making skills in her audience (Munro & Robertson 2004). In discussion with the current author Senga Munro (2004) described her approach in the case of autism, this would be to expose the child with autism to many *personalised* stories. While this is not the approach taken in this work, it is not in conflict with the TouchStory approach. TouchStory is not an end in itself, rather its purpose is to give additional hooks, or another way into narrative comprehension, so that more can be made of opportunities such as those described by Munro.

Narrative may be used as a vehicle in sensitive or stressful situations. Allison Druin and her colleagues have conducted a number of studies encouraging children to tell their own stories. Collaboration is central to Druin's approach (1999). In the case of (Plaisant et al. 2000), in which narratives were elicited from children in paediatric rehabilitation by using toy-like robots as intermediary storytellers, the children were involved in the *design* of the robots. Montemayor, Druin and Hendler (2000) consider a personal electronic story teller in an educational context. Aylett and Louchart (2003) use emergent narrative in the context of personal and social education issues such as bullying and refugee integration using '*virtual role-play with synthetic characters that establish credible and empathic relations with the learners*'. This allows a participant to contribute to the narrative and observe and reflect on the outcomes in a safe environment. These were carried out in two European projects VICTEC (2006) and eCircus (2003). On a smaller scale, Woods et al. (2005) investigated the potential of children's stories based on pictures of robots as a vehicle for socially sensitive issues in a typical school population. The issue they addressed was that of bullying. They found that the children enjoyed using the robots within a narrative context, and that the stories provided a useful tool to elicit the children's attitudes on sensitive issues.

Massaro (2006) describes an embodied agent and storytelling techniques used with children with language challenges, including children with autism. The focus of the work was on improving language, and it was found that children with autism were able to learn and remember new words. (As a personal aside: the presentation of this work at ICCHP 2006 gave insights which were used in the design of trial 3 of the current study).

Recent work by Stirling and Barrington (2007) is concerned with eliciting spontaneous written narrative from children with autism in order to assess linguistic performance. They note that a benefit of using a computer-based environment is that social impairment does not confound measures of linguistic performance. Their interest focuses on in-depth qualitative analysis of spontaneous narrative in contrast to the experimentally constrained narratives required by an experimental approach and statistical analysis. They found some excellent narrative skills in their participant (a boy aged 7) including an ability to present a macrostructure and devices for managing perspective. Nevertheless, they found some aspects of his storytelling ‘profoundly unusual’.

The studies described above differ from the current study in that they assume and depend on narrative skills whereas the current study aims at promoting an understanding of narrative structure *per se*.

2.9 Chapter Summary

This chapter established the motivation for helping children with autism to improve their narrative skills, and considered the requirements of a learning environment designed to provide such help. The current work was placed in context by considering the wide variety of ongoing active research into areas of assistive technology for children with autism and the use of narrative in education and learning environments.

The following points were established with regard to the motivations behind the work described in this thesis and the means that were adopted:

- Narrative is crucial for social interaction.
- Autism is a social deficit.
- Children with autism have specific difficulties with narrative.
- Helping children with autism overcome their difficulties with narrative may help them improve their social comprehension.
- Computers can provide a comfortable environment for children with autism.

In determining a means to provide such help, the following were considered:

- the characteristics of autism, keeping in mind that autism is a spectrum disorder and children with autism may differ greatly,
- the particular needs of children with autism in an educational context,
- the preference of children with autism to seek coherence (integration and sense-making) at a local rather than global level,
- previous and ongoing research into computer- and robot-based assistance for children with autism,
- engagement in learning environments with reference to the concepts of 'flow' and a 'zone of proximal development',
- the generic challenges faced by designers of educational software,
- the tension between the need of children to be in their zone of proximal development for good learning to take place, and the needs of children with autism who find failure debilitating, and need time to enjoy their mastery of a skill before moving on.

3. CHAPTER 3: THE PROTO-NARRATIVE APPROACH

3.1 Preamble

Chapter 2 established the motivation for helping children with autism to improve their narrative skills. It was noted that autism is a spectrum disorder, rendering prediction and generalisation unreliable when applied to specific cases. It was noted, nevertheless, that children with autism have a preference for local integration rather than global integration, looking for sense in matters of detail rather than attending first to the whole. Local integration, which means making sense of things, or not, by attending to matters of detail, may lead to the confusion of detail described by Ros Blackburn (Blackburn 2003; Happé 1997; Plaisted, Swettenham & Rees 1999). This state of affairs inspires and informs the approach taken in the current work, which is to address the individual components of narrative independently, adapting to reflect the abilities and needs of individual children. The term proto-narrative, which is used to mean a sequence addressing one aspect of narrative, is explained in this chapter, as is the proto-narrative approach adopted in this work.

3.2 Theories, modes and components of narrative

To describe the proto-narrative approach adopted it is first necessary to describe four aspects of narrative theory, these being: the distinction between the story and the narrative discourse; modes of discourse; gaps in the narrative discourse; and the components and structure of the story.

3.2.1 Story and narrative discourse

Recall from Chapter 2 that views vary widely on the nature of narrative. It is defined by Porter Abbott as '*the representation of an event or series of events'* (Porter Abbott 2002). While he acknowledges that some authors require at least two temporally ordered events, and yet others require the events to be causally related, his stance is that these are unnecessary restrictions; that the capacity to represent an event is the key building block. Thus a narrative has two principal components. First the story, this is the heart of the matter, chronologically ordered, temporally constrained to the order in which events happened (in reality or in imagination). Second the presentation of the story, otherwise called the narrative discourse, which is under no such temporal constraint (Porter Abbott 2002), part of the narrator's skill being to control the unfolding of events. As the aim of the work presented here is to foster an understanding of narrative *per se*, it is concerned with straightforward narratives in which the temporal ordering of the presentation follows the temporal constraints of the story; that is narrative in which the chronology of the presentation follows the chronology of events in the story.

3.2.2 Modes of discourse

Manfred Jahn describes two main modes of narrative discourse '*scene by scene'* (isochronous) and '*summary*'. He sets this in the context of the traditional distinction between '*showing*' and '*telling*'. In the case of showing (mimesis) '*there is little or no narrational mediation, overtness, or presence. The reader is basically cast in the role of witness to events*', the skill of the narrator being in selecting what to show, that is, in what to select for attention. In the case of telling '*the narrator is in overt control (especially durational control) of action presentation, characterisation, and point of view arrangement.*' (Jahn 2003, paragraph 5.3). Porter Abbott (2002) points out that it is generally accepted that most narrative presentations interleave these modes of discourse, moving from one to the other. As the overall aim of the current work is to help children with autism to make more sense of the socially constructed aspects of their lives, in which events unfold without an authorial voice, there is a clear interest in the 'showing' mode, and this was the mode adopted in the current work. However the 'telling' mode more easily contains evaluative review and retrospective sense making, domesticating surprise and rendering events coherent. It is the commonly used mode to convey tacit knowledge, especially to warn the listener of possible dangers. A long-term goal of the current work is to make the telling mode more accessible to children with autism so that they may benefit from such tacit knowledge.

3.2.3 Over-reading and gaps in the narrative discourse

Recall from section 2.2.1 that story-listening is an active process. Porter Abbott expresses it thus: '*we never see the story directly, but instead always pick it up through the narrative discourse. The story is always mediated … so that what we call the story is something we construct*' (Porter Abbott 2002, page 17). '*We are always called upon to be active participants in narrative, because receiving the story depends on how we construct it from the discourse*' (Porter Abbott 2002, page 19).

Of particular relevance to the approach taken in this work is the concept of a *narrative gap*. '*… narratives by their nature are riddled with gaps'* (Porter Abbott 2002, page 83).

Consider 'Yesterday we went to the woods…', this contains at least the following narrative gaps, which may, of course be filled for us later in the narrative: yesterday with reference to when? Who are we, are we people? How many are we? What woods, what sort of trees? Have we been to the woods before? A narrative gap is not made explicit by the narrative discourse, but is filled during the process of active story construction. Filling such a gap is an example of over-reading, which is the process of incorporating material which is not signified in the narrative discourse. To some extent over-reading is inevitable as gaps in the narrative discourse are unavoidable and may be specifically intended if the storyteller wishes to introduce ambiguity. So, in actively constructing the story it is necessary to fill *gaps* in the narrative discourse. In general, there may be many ways in which a particular narrative gap may be filled, leading to multiple interpretations of narratives. Note that the converse of over-reading is under-reading, which occurs when the constructed story omits material which is present in the narrative discourse.

The current work is concerned with helping children with autism fill small narrative gaps in coherent ways, so they are better able to construct a story which makes sense to them, and is also seen as coherent by others.

3.2.4 Components of the story

The interest in this current work is in promoting an understanding of narratives 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), described in section 2.2. Such stories have a break in a steady state, a challenge to be faced or difficulty to be overcome, followed by a restoration in which some steady state is restored. It is this format which, through familiarity with the pattern, domesticates surprise.

Recall that a story is a *temporal sequence of events* (possibly only one) involving *entities*. Entities are of two basic kinds; those capable of agency are called *characters*, those not capable of agency are, usually, part of the *setting*. Events are either *actions* caused by characters, or they are *happenings*, that is, things which happen and have an effect on entities. Note that the character/setting distinction is not simply one of agency; the crucial distinction is between the subjects of the story and the setting. An example of a subject which does not have agency would be, say, a balloon in a narrative describing what happened to the balloon when it floated away. Most subjects can be thought of as characters, this is the term used in the literature, and is the term used here even where agency is absent. This is relevant as many of the ‘characters’ used in TouchStory do not have explicit agency.

3.3 Identifying proto-narrative categories

The first stage in identifying proto-narrative categories in order to address them separately in the current work was to make a distinction between the sequence of events and the entities, giving the commonly described components of narrative shown in Figure 3-1 .

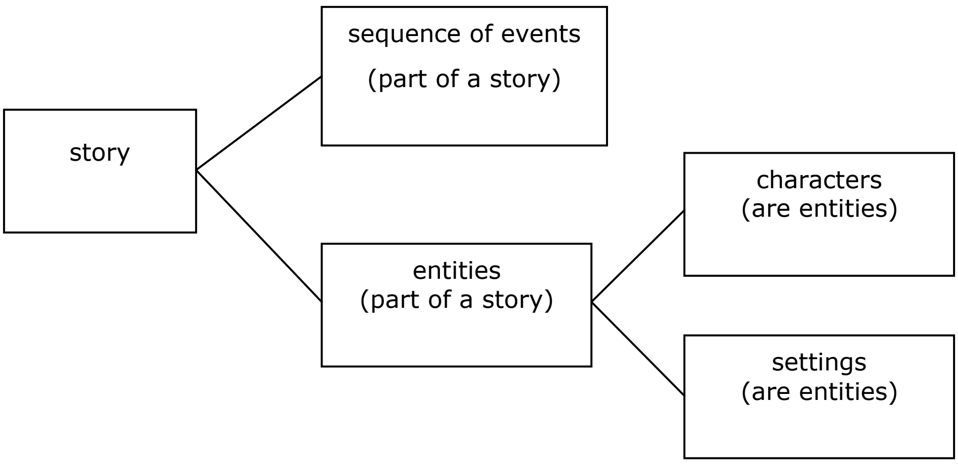


Figure 3-1 Components of a story

However a sequence of events is a complex thing, especially one which follows the format of a story worth telling. Constraints on the sequence of events were relaxed in order to address aspects of sequences in isolation. The following were identified: first, simple sequences, with no temporal imperative, which can be read as meaningfully backwards as forwards, these were named reversible sequences; second, time ordered sequences which are limited to happenings which may involve causality but not intent or emotion, these were called temporal sequences. And third, sequences in which emotions or intent are involved, these were called narrative sequences. This taxonomy of proto-narrative categories is illustrated in Figure 3-2, and was first published in Davis et al. (2004).

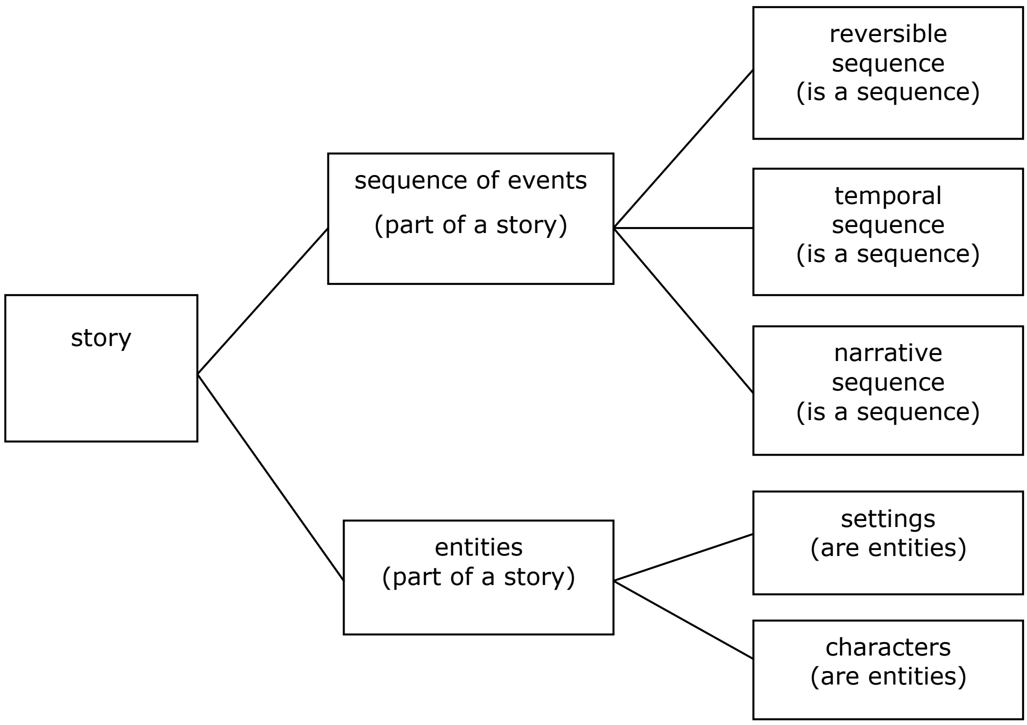


Figure 3-2 A taxonomy of proto-narrative categories

3.4 Picture narratives

A proto-narrative resembles a narrative in that it has a presentation and a 'story', but the story is rudimentary, containing *one* component of a fully developed story. What then of the proto-narrative discourse, how is the rudimentary story to be conveyed? The current work is not concerned with reading ability; it is concerned with helping children with autism to understand what narrative is. Therefore the discourse used in the study should not rely on an ability to read. A number of media can be used to convey narrative or proto-narrative without requiring reading, for example, movie clips or virtual worlds. The chosen medium was that of the picture-narrative, chosen precisely because still pictures are still, and can be studied at the viewer's own pace.

The term picture narrative is used here to mean a story told through *'a series of interconnected pictures'* sometimes referred to as *'stories without words'* (Matulka 1999). While there are many picture books for children, there are relatively few that are both wordless and of the narrative genre; most are thematic, illustrate sequences, or illustrate scenes from an accompanying text. However picture narratives for children do exist, and a list of 50 wordless picture books (not all currently in print) can be found in (Matulka 1999).

‘Comics’, whether for children or adults, is a concept that has much in common with picture narrative. Comics may, but need not, contain text, typically speech bubbles in addition to images. Scott McCloud gives a number of definitions for comics, he considers ‘*sequential art*’ the best definition, but also provides ‘*juxtaposed pictorial and other images in deliberate sequence*’ (McCloud 1993, page 199). Thus a comic consists of a number of panels (sometimes called panes), in a deliberate order, together with the space between the panels, known in comics vocabulary as ‘the gutter’. Narrative construction combines the happenings in the panels with assumed happenings in the printed gutter. The process of creating continuous sense from two or more juxtaposed still images is known as ‘closure’. McCloud describes the comprehension of comics thus; ‘*Comic panels fracture both time and space, offering a jagged, staccato rhythm of unconnected moments. But closure allows us to connect these moments and mentally construct a continuous, unified reality.*’ (McCloud 1993, page 67). He refers to the space between the panels as central, *'the very heart of comics'*. So, the gutter is important, providing clear gaps in the narrative discourse, and this fact is relied on in this work.

McCloud describes several distinct categories of panel-to-panel transition. Moment-to-moment transitions show very small changes between panels and require very little closure; many of the transitions used in the current work are of this form. Action-to-action transitions show distinct actions of a single subject and require more closure but are of the same quality as moment-to-moment transitions; these are also used in this work. Scene-to-scene transitions are transitions across significant distances of time and space and these occur in some of the simple picture narratives used here. Transitions not used include subject-to-subject transitions which show different aspects of the same scene while remaining within an ongoing temporal framework, aspect-to-aspect transitions which present different aspects of a moment, and non-sequitur transitions, which are self explanatory.

3.5 The development of the t-story concept

The term t-story was introduced to mean a proto-narrative or simple picture narrative with a particular form of discourse, in particular as a game. The t-stories are presented as picture sequences, in which all the pictures are visible at one time, with gaps between the pictures, as in a comic. Focus is brought to both the proto-narrative category and the narrative gap, while at the same time providing an active enjoyable experience, by presenting the proto-narratives as a fill-the-gap game. A t-story could be represented abstractly as a list of panels followed by a set of options, as follows:

$$[1 \rightarrow pic1,\ 2 \rightarrow pic2,\ 3 \rightarrow \Diamond,\ 4 \rightarrow pic4] \ / \ (optionA,\ optionB,\ optionC)$$

This is read as:- picture pic1 is in position 1, pic2 is in position 2, position 3 is empty, and pic4 is in position 4, which picture from (optionA, optionB, optionC) best fills the gap at position 3. Theoretically the number of positions in the list is unlimited, and the empty position can be at any point in the list. However in order to give concrete examples, these must be rendered in some way. The illustrations used in this chapter were created by the TouchStory program used in this work. Issues of screen design and how a t-story game is played are discussed in Chapter 4.

The t-story layout and terminology can be seen in Figure 3-3. The term panel is taken from comics literature (McCloud 1993), and the terms option and distracter are taken from objective testing literature (Pearsall 2001). The list is to be read left to right; the teachers involved with the trials were very resistant to any more open approach to ordering. Note that although option 1 in Figure 3-3 is labelled the 'correct' answer, and this was the term used, which reflects a state of mind, in fact it is not a matter of right or wrong. It is rather a matter of which option requires the least over-reading of the narrative gap which is created by the empty panel. Some other choice may make more sense to an individual; Scott McCloud (1993, page 73) asserts that meaning can be made of any two juxtaposed panels. It could be said, then, that t-stories promote an 'Occam's razor of narrative construction', in which the simplest explanation (that is the one which minimises both over-reading and under-reading) is the most favoured. (Recall from section 3.2.3 that over-reading is the necessary process of incorporating material which was not signified in the narrative discourse into the mental construct of the story, similarly under-reading is the process of omitting material which was signified in the narrative discourse into the mental construct of the story).

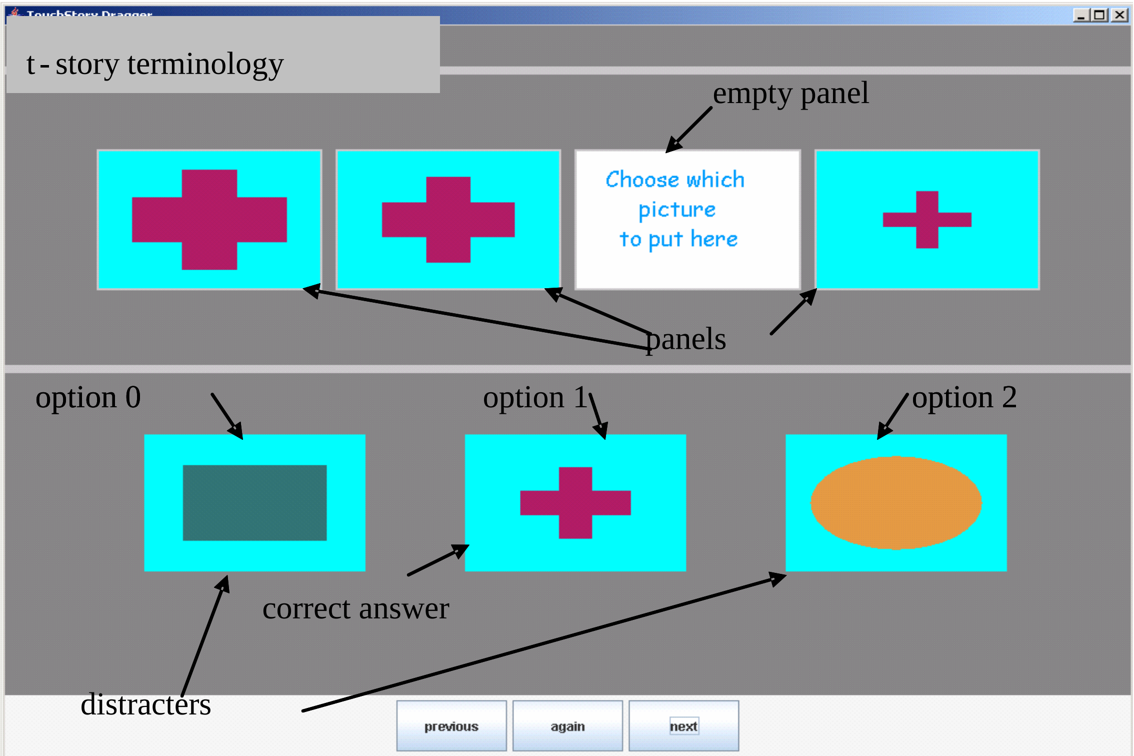


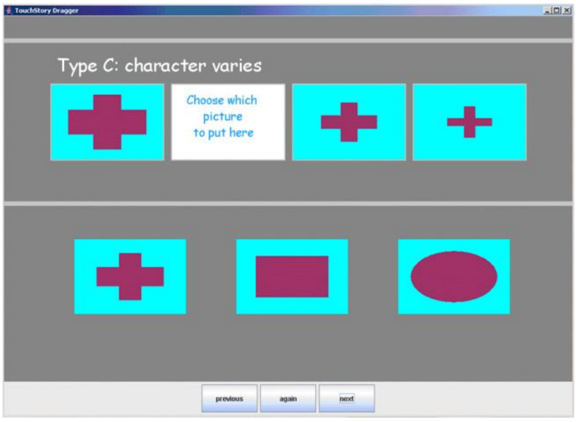
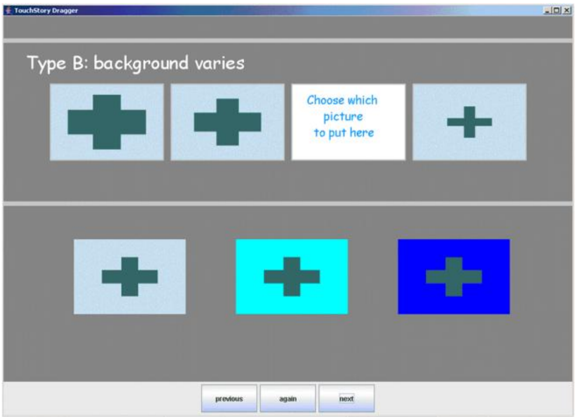
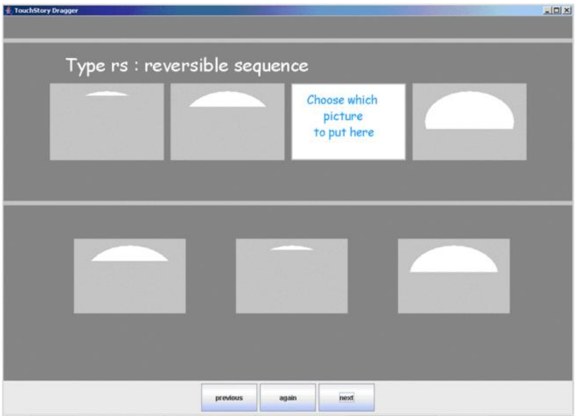
Figure 3-3 t-story terminology

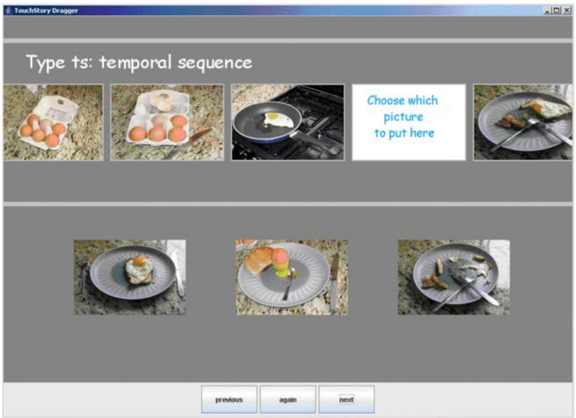
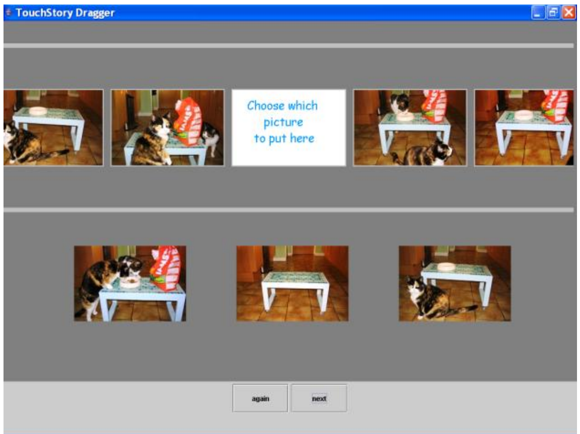
An example t-story is shown in Table 3-1 for each proto-narrative class as follows:

- T-stories of type c present proto-narratives of the category ‘character’, an example is given in Figure 3-4.
- T-stories of type b present proto-narratives of the category ‘background’ or ‘setting’, an example is given in Figure 3-5.
- T-stories of type rs present proto-narratives of the category ‘reversible sequence’, an example is given in Figure 3-6.
- T-stories of type ts present proto-narratives of the category ‘temporal sequence’, an example can be seen in Figure 3-7. Notice that some t-stories, such as Figure 3-7, require experiential or semantic knowledge of the events portrayed; care was taken that the events represented were within the child’s experience, and indeed the t-stories were prepared to fit in with the participants’ term projects and events.
- T-stories of type ns present simple picture narratives and proto-narratives of the category ‘narrative sequence’, an example can be found in Figure 3-8.

The production and moderation of the t-stories is discussed in Chapter 4.

Table 3-1 Table of proto-narrative examples

Caption	**Figure**
Figure 3-4 A t-story of type c. *Type c addresses character variability and continuity by presenting a choice among 3 different characters; in this case, different shapes.*	
Figure 3-5 A t-story of type b. *Type b addresses background variability and continuity by presenting choice among 3 different backgrounds; in this case backgrounds of differing colour.*	
Figure 3-6 A t-story 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*	

Caption	**Figure**
Figure 3-7 A t-story of type ts. *Type ts addresses temporal aspects of sequences of events by presenting a choice among stages of a temporal sequence*	
Figure 3-8 A t-story of type ns. *Type ns addresses sequences of events which contain actions or emotions.*	

3.6 The adaptive approach adopted

Recall from section 1.3.1 that, informed by the ideas of Gorayska et al. (1997; 1999; 2001; 2002), an aim of TouchStory was that it adapts to the cognitive needs of individual participants. By addressing the components of narrative individually, it is possible to adjust the relative representation of each component (i.e. the number of t-stories from each proto-narrative category) for individual participants, so that sessions reflect each participant's needs and abilities with respect to narrative.

The aim was to make small adjustments from session to session, in keeping with the need to provide a comfortable and predictable environment. The approach taken was to develop a profile of each child over a number of sessions, in terms of his or her success with each proto-narrative category, and then to vary subsequent sessions according to a simple function applied to that profile. The profile was updated after each session so that adaptation, when applied, was always current.

Crucial to the approach was that a simple initial formula was trialled and evaluated. If necessary, in response to the evaluation, the complexity of the formula would be increased, forming an elaboration cycle. The approach of the first adaptive formula was to decrease the number of t-stories from proto-narrative categories in which the participant had, over recent sessions, demonstrated he or she could do well, and increase the number of t-stories from the remaining proto-narrative categories, thus gradually increasing the proportion of t-stories from categories the participant needed to practice.

It is perhaps helpful to note that while TouchStory has superficial similarities to computerised adaptive testing, they are in fact rather different, both in intent and in the underpinnings of the adaptation. First, TouchStory is not concerned with assessment *per se*, rather, as previously described, the aim was to provide a cognitive prosthesis. Second, TouchStory does not and cannot assume any ordering of difficulty between the proto-narrative categories, the issue being to identify what *a particular child* found difficult. In contrast computerised adaptive testing generally relies on the relative difficulty of any particular item being determined *a priori* in some way, for example by having the results of answers given by a large population (Wainer 1990), or by classification according to some measure of difficulty such as Bloom's taxonomy, as in (Lilley, Barker & Britton 2005).

3.7 Research questions raised by the proto-narrative approach

It has been shown that it is possible to identify components of narrative as proto-narratives and provide representations of them as t-stories (games based on the closure of picture sequences) such that each component can be considered independently.

The research questions framed in Chapter 1 are revisited and are now refined in terms of the concepts developed in this chapter, these being:

- the proto-narrative concept,
- t-stories as instances of proto-narratives,
- the introduction of a means of developing an adaptive formula to address individual learning needs with respect to proto-narratives.

The outstanding research questions become:

- Is it possible for an interactive learning environment to present proto-narratives as a game based on the closure of picture sequences, specifically as t-stories, which are appropriate for children with autism? That is:

1. Would children with autism be able to use such a system?
2. Would children with autism be engaged, and enjoy using the system as intended (rather than for some other purpose)?
3. Would a computer-based presentation have any adverse impact when compared with a similar activity in the real world?

- Does skill with proto-narratives as t-stories reflect skill with the narratives of everyday life?
- Do children with autism, as individuals, not as a population, find some proto-narrative categories more difficult than others?
- Can an adaptive formula be developed and used to reflect individual abilities with respect to proto-narrative categories and thus address individual learning needs, given that an ordering of difficulty is not known *a priori* for any individual child, and may differ among children?
- Can children with autism learn from using such a system? In particular does learning, if any, transfer to other related tasks or indeed generalise to the real world bringing about improved skill in the comprehension and construction of the fully developed narratives encountered in everyday life?

3.8 The TouchStory design framework

The approach adopted with respect to the above research questions was to design, develop and trial three successive TouchStory prototypes, developing the prototypes in an incremental manner. The development framework for each of the three development rounds is shown in Figure 3-9. This figure has been inspired by one in Neale, Cobb and Wilson (2001) which presents a methodology for involving users with learning disabilities in the design of virtual environments. While in this thesis the involvement of users was indirect and was achieved through observation, the gross structure of the framework remains appropriate. Each design round consisted of three phases:

- the ideas generation phase,
- the prototype development phase,
- the experimental study and evaluation of experimental results.

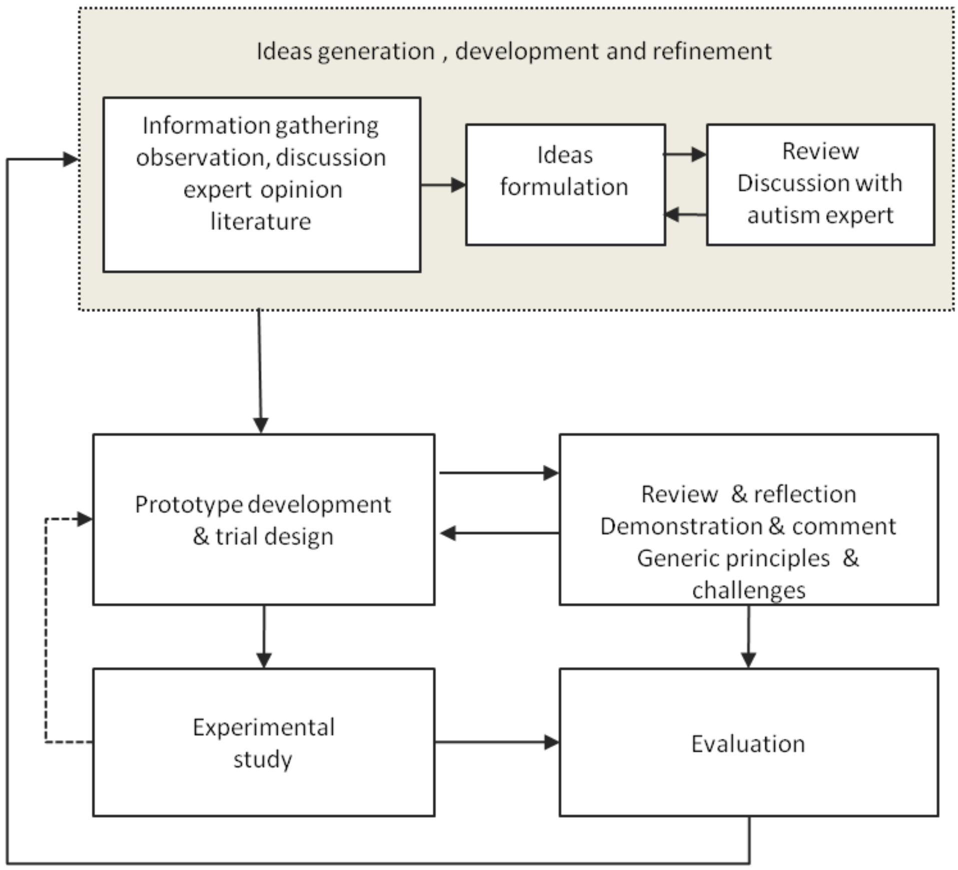


Figure 3-9 TouchStory Development Framework. This figure has been inspired by one in Neale, Cobb and Wilson (2001). The major developmental pathways are indicated by solid lines with arrows. Feedback within an extended study is indicated by a dashed line with arrow.

The ideas generation phase. Information was sought from a number of sources during the ideas generation phase: from scholarly literature and discussions with researchers in similar fields; from observation of potential and actual participants; from informal discussion with professionals such as teachers, a speech therapist, and one-to-one support staff in daily contact potential or actual participants; from autobiographical accounts, both spoken and written, given by adults with autism; and from discussion with an academic expert in the field of the education of children with autism. Once ideas were formulated, using drawings, or, in later rounds, screenshots, these were reviewed in consultation with this expert. The product of the ideas generation stage was not only a specification of the prototype, but also the way in which the prototype was to be used. That is, decisions about the ways in which t-stories were to be produced; the presentation order of t-stories during a session; whether there was to be one session or many, and if many, how the t-story schedule would be varied from session to session.

The prototype development phase: Once the prototype was developed there was a process of reflection and review during which the prototype was shown to teachers in daily contact with the participants for comment and re-confirmation that they were comfortable with the project. In some rounds more than one variant of the prototype was prepared and demonstrated, see for example, Chapter 6. Also found at this stage is a process of reflection in which the prototype was considered in the context of pervasive overarching guidelines or generic questions. For example, TouchStory version 2 was reviewed against Luc Steel's guidelines for educational environments (see section 2.6.1), and the ways in which these guidelines were met was reviewed and clarified. This review and reflection informed the trial design, the ongoing monitoring of the experimental study, and the evaluation stage.

The experimental study and evaluation of experimental results: The major output of the experimental study was to the evaluation procedure which followed it. However, as the experimental studies involved long term trials in which the participants were seen on many occasions, there is also intra-trial feedback which allowed a prompt response to unforeseen issues; this is shown as a dashed line in Figure 3-9. The output of the evaluation stage fed into the development and refinement of ideas for the design of the next TouchStory prototype.

The development of the TouchStory prototypes and the experimental studies are covered in Chapters 4, 5, 6, 7 and 8 but it is helpful at this point to consider the ways the various strands of literature introduced in Chapters 2 and 3 fit into the development framework. In order to keep the diagram presented in Figure 3-9 relatively uncluttered, the literature contributing to each development round is shown separately in Table 3-2. Note that this table shows the points at the various literature strands were *used* in the incremental development of TouchStory, rather than the points at which they influenced the development of ideas in this thesis. For example, the proto-narrative and adaptive concepts which are central to this thesis were developed prior to the design of any software, but were not pertinent to the research questions addressed by the development of TouchStory version 1.

It can be seen from Figure 3-9 that literature contributed at two points in the development of each prototype. One body of literature fed directly into the design of the prototype by influencing the ideas formulation. The second, more generic, literature provided pervasive guidelines or challenging questions which were used as a basis for reconsidering the prototype from an independent perspective as described above. In Table 3-2 the former body of literature is shown in the column called ‘Information gathering’ and the latter in the column called ‘Review and reflection’.

Table 3-2 Literature influencing the design of TouchStory prototypes. The column ‘information gathering’ refers to literature which fed directly into the design of the prototypes by influencing the ideas formulation; the column ‘review and reflection’ refers to that which provided pervasive guidelines or challenging questions. This table accompanies Figure 3.9

Prototype	**Information gathering**		**Review and reflection**	
	topic	**thesis section**	**topic**	**thesis section**
TouchStory version 1	Autism as a deficit in social interaction	2.3	No additional literature was considered at the review and reflection stage in of the design of TouchStory version 1	
	Autism and narrative	2.4		
	Autism and learning Characteristics common in autism Educational approaches	2.5 2.5.1 2.5.2		
	Playful approaches to learning	2.6		
	Assistive technology Other studies with robots and interactive software	2.7 2.7.1 2.7.2 2.7.3		
	Narrative comprehension Theories of narrative Modes of discourse Gaps in narrative discourse Picture narratives	2.2.1 3.2 3.2.2 3.2.3 3.4		
TouchStory version 2	as above, plus		Steels’ design principles for learning environments	2.6.1
	Development of the proto-narrative concept	2.2.1 3.2 3.2.4		
	Design of first adaptive formula (applied by hand in this version, automated later)	3.6		
TouchStory version 3	No additional areas of literature were considered during the development of TouchStory version 3		as above, plus…	
			du Boulay’s generic challenges in educational software	2.5.2
			Vygotsky’s zone of proximal development	2.6.2

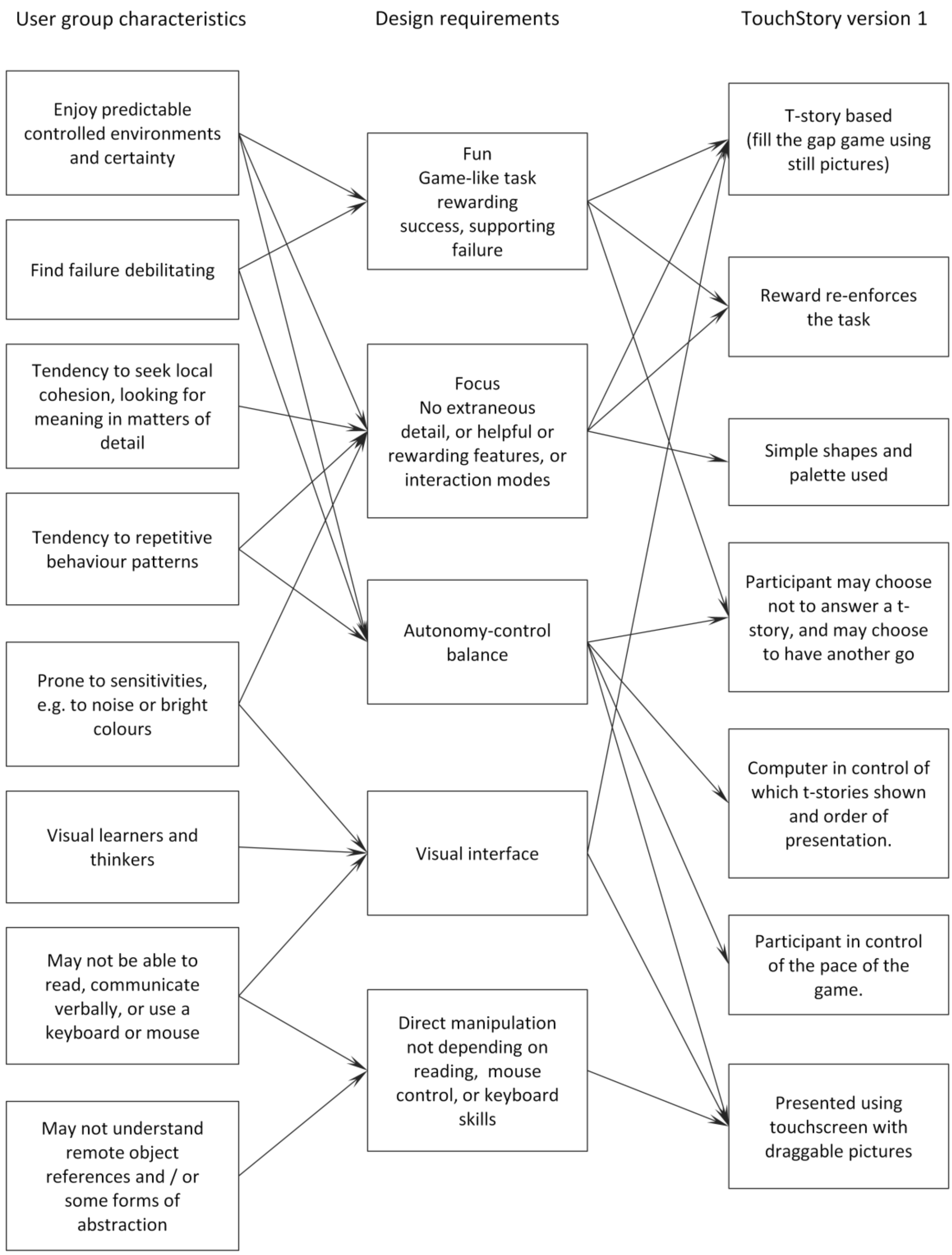


Figure 3-10 TouchStory Design Framework. Characteristics common in children with autism are shown in the left-hand column. The requirements these placed on the design of TouchStory are given in the central column, and the ways in which these requirements were met in the first TouchStory prototype are given in the right-hand column.

The impact of the ideas generation and formulation stage of the TouchStory development framework (see Figure 3-9) on TouchStory version 1, the first prototype, is illustrated in Figure 3-10. Characteristics commonly found in children with autism are shown in the left-hand column of Figure 3-10 and were compiled from the literature on autism referred to in Table 3-2 together with other information gathering techniques referred to in Figure 3-9. These were refined into the set of five general requirements placed on the design of TouchStory shown in the central column of Figure 3-10. These were that TouchStory should be designed to be fun; the interface should be highly focussed, avoiding detail which might cause confusion; there should be a balance of control between TouchStory and the participant, giving the participant control while keeping the game focussed; the interface would be visual; and manipulation would be direct. The ways in which in which these overarching requirements were manifest in TouchStory version 1 is shown in the right-hand column of Figure 3-10. The resulting ideas for the interface were presented as paper-and-pencil diagrams and mock-up screenshots which formed the basis of discussion with an academic autism expert. Once the prototype was developed it was again discussed with the academic autism expert and autism practitioners as previously described.

3.9 Chapter summary

This chapter presented the proto-narrative and t-story concepts which are developed in this thesis and explained their basis in narrative theory.

The following points from theories of narrative and narrative comprehension were established:

- There are two aspects to a narrative, the story and the narrative discourse (that is the presentation of the story).
- The story is an internal construct, communicated via the narrative discourse.
- The discourse necessarily does not tell ‘the whole story’, there will be gaps, things not signified, in the narrative discourse.
- Narrative comprehension is a creative participatory process in which narrative gaps are filled in a search for coherence.
- Picture narratives have a particular form of narrative gap which is the space between the panels. This space is known as the gutter. The creative act of constructing a narrative

from the happenings in the panels and the assumed happenings in the gutter is called *closure*.

- The characters, the setting and the sequence of event which occur are components of narrative.

The development of proto-narrative categories was described, as was the potential of proto-narratives to facilitate focus on individual narrative components (such as characters or settings) allowing them to be considered and varied independently. T-stories were described as a visual form of narrative discourse in which proto-narratives and simple picture narratives are presented as a game with particular emphasis on the concept of *closure*. This form of narrative discourse does not require reading skills and is suitable for children with autism who are in general highly visual learners.

The approach to adaptation to individual learning needs developed in this thesis was introduced in this chapter, in particular:

- The need for a new means of adaptation to individual learning needs, given that no ordering of difficulty is known among the proto-narrative categories, was established.
- The aim of the adaptation to individual learners was described as being to present participants with more examples from proto-narrative categories which they need to practice while still providing a successful and enjoyable experience.
- A new adaptive approach was proposed in which, over multiple sessions, a simple function is applied to the participant's recent profile in order to vary subsequent sessions.
- The approach proposed to developing the adaptive function was described as being to trial and evaluate a simple function and increase the complexity where necessary over successive long term trials.

Last, research questions arising from the proto-narrative approach were formulated and the approach adopted to these questions, in particular a design framework for the development of TouchStory, was presented.

4. Chapter 4: Interactive system development-TouchStory

TouchStory was developed, within the frameworks described in section 3.8, for children with autism. The design and development of TouchStory took into account of both the characteristics and preferences of children with autism, as described in section 2.5, and the characteristics of an enjoyable, engaging activity, described in section 2.6, which are revisited in section 4.11.

4.1 The rationale for an interactive software system

The rationale for developing an interactive software system to play a game such as TouchStory, which is based on picture narratives and could be played as a traditional board game or presented as a sticker book activity, is as follows:

- The task of managing, storing, and presenting t-stories is handled by the software system.
- Monitoring, logging and storing each participant's interaction with the game may be handled by the software system, making it *feasible* to adapt the game to the narrative abilities of individual participants.
- Children with autism typically enjoy using computers, and may find the *same game* more engaging when presented as a computer game.

An interactive software system can combine benefits of a board game with those of a sticker-book activity:

- The child may go at his or her own pace (as with a sticker book).
- Social interaction is not necessary to engage with the task, freeing the child to choose to interact with the attending adult on his or her own terms (as with a sticker book).
- There is immediate feedback on whether an answer is correct (as with a board game played with an attending adult).

While it is possible to imagine more ambitious ways to present proto-narratives, for example, one could imagine a three dimensional interactive space in which the pictures were physically moved and placed by the child, such solutions were not considered. Evaluation of such solutions is not part of this thesis; such a system might or might not have been better. The current author would postulate that, as the t-story activity is essentially a constrained, two dimensional task and spatial manipulation was not a focus of the study, the third dimension would provide more opportunities for behaviours which are not 'on task' without offering benefits.

The guiding principle of this work was to begin simply and introduce complexity only where necessary. In accord with this principle TouchStory replicates the game as it would be in the physical world, with the action of moving a picture in the real world modelled by dragging a virtual picture across the workspace provided by the screen.

4.2 The rationale for a touch screen as the interaction device

Difficulty with proto-imperative pointing and remote object references is characteristic of children with autism (see Chapter 2). Therefore the first requirement of the interaction device was that it affords direct manipulation of pictures in a t-story game. Finding 'the best' interaction device for this purpose was not an aim of the research. It was decided to use a touch-sensitive screen, in particular a touch monitor which did not require a pointing device (or more properly, for which a finger may be used as the pointing device) used together with a laptop computer. Use of a touch-sensitive whiteboard was rejected as, although it would afford much larger bodily movements and scope for joint attention, it would have required participants to come to an installation provided by the University of Hertfordshire on a regular basis over several months. Practically this was not feasible and importantly, it would not be appropriate for children with autism, who are typically resistant to change in routine and find new experience daunting. Graphics tablets were also rejected as the ones seen were smaller, making joint attention more difficult, and required an (easy to lose) intelligent pointing device.

The particular touch monitor selected was the Iiyama AS4611UT, which is an 18.0 inch (45.5 cm) TFT colour LCD monitor, bought for the study in 2002. It was chosen with regard to the following criteria: robustness, ability to withstand grubby conditions, size of screen, quality of display, the cost, and the weight (6.6 kg). This last was important as it was necessary to carry it to and from sessions since neither of the participating schools was happy for it to be left on the premises.

4.3 Development strategy

As discussed in sections 1.3.1 and 3.6 the methodological and conceptual frameworks for the development of TouchStory recognised the need for humane interfaces (Gorayska, Marsh & Mey 1999) that is, ones developed within the recognition that not only do humans transform their environments, they are in turn transformed by their environments.

The approach taken to the development of TouchStory was exploratory, child-centred and iterative, following the framework described in section 3.8. Observations of children with autism using one version of TouchStory were used to inform the development of the next version of TouchStory.

4.3.1 Development Challenges

Development and evaluation of software for children with autism presents a dual challenge. On the one hand the characteristics of autism such as lack of flexibility, a tendency to focus on matters of detail, difficulty with references to remote objects, etc. as described section 2.5, mean that it is particularly important that the design is fit for this particular user group. On the other hand as autism is a deficit in the ability to understand and interact in the social world, many user-centred design techniques are not appropriate; this was noted by Andersson et al. (2006) in the context of the design of virtual environments for children with autism and by Robins et al. (2007) in the context of eliciting the requirements for a robotic toy for children with autism. Neale at al. (2001) found, in the context of involving users with learning disabilities in the design of virtual environments, that some of the most commonly used evaluative methods could not be used or had to be adapted to be applicable to their user group.

In particular, in the current study it was noted that collaborative design, in which children are design partners, such as that done by Allison Druin et al. (Alborzi et al. 2000; Druin 1999; Montemayor, Druin & Hendler 2000) was not possible. Even with typically developing children Druin et al. found that it took 6 months of time and patience to build an effective intergenerational design team. However, Druin explains that she does not have just one technique for cooperative design, rather she has several from which the researcher may pick and choose, assembling the chosen techniques as appropriate. Of the techniques recommended by Druin, contextual inquiry, in which data is collected in the user's own environment (Druin 1999), is relevant to the current study. Indeed, given the difficulties children with autism have with new experiences and changes to routine one may argue that it is essential. While focus groups are less immersive than cooperative design, they are also not appropriate; some participants may have very little productive language, or may not speak at all.

Recall from section 1.3.2 that Nielsen recommends talking to users who will actually use the system, not their managers (or teachers) in order to evaluate a system (Nielsen 1993, pages 1 and 165). Neale et al. (2001) in their paper on including users with learning disabilities in the design process, also stress the importance of accessing the views of the users and not just the views of the professional working with them. However, commonly used protocols, such as thinking aloud protocols, which Nielsen strongly recommends, are not suitable. As Nielsen observes, thinking aloud protocols are hard for users to do and in particular are hard to use with children.

4.3.2 Development approaches

The methodological approach taken by Robins et al. (2007) in eliciting the requirements for a robotic toy for children with autism, used informant design an proposed by Scaife and Rogers et al. (1997). Stakeholder panels of parents, teachers, carers and expert researchers (but not children) were set up to give an understanding of the design space, and, sometimes contradictory, views of the initial requirements. Their intention was to involve children with autism at the next stage, by using observational exploratory studies to investigate specific design concepts.

Neale, Cobb and Wilson (2001; 2002) also used different stakeholders to inform different stages of the design of virtual environments for adults and adolescents with autism. They worked with people with high functioning autism and were able, not only to observe, but also to question their participants about the virtual environment. Neale, Kerr, Cobb and Leonard (2002) took an ethographic approach to evaluating a virtual environment in a special needs classroom by allowing teachers and pupils free reign to use the virtual environment as they wished, the researchers offering only technical support.

Gorayska et al. (2001) stressed the importance of careful consideration and clarification of what is meant by the term ‘the users’ of a software system. They indicated there may be many such groups with differing needs, in particular they cite end-users and technical support. In these exploratory studies the users of TouchStory can be identified as the children using the software and the experimenter exploring the proto-narrative concept. Other stakeholders were the professionals and parents concerned with the well-being of the children. Therefore, the approach taken to software development was to design a software system specifically for children with autism following the development framework presented in Figure 3-9, taking into account detailed guidance from an expert researcher in autism, informal discussion with other stakeholders, and observation of potential participants. The process was iterative and extended evaluation trials were carried out in each phase. The approach taken to evaluation was to observe interactions, to this end sessions were recorded both by videotaping them and by creating software logs. The trials were carried out in the participant's own environment (at their schools) providing ecologically valid contextual inquiry. The TouchStory interface differs from that of a robot or virtual environment in that the interface itself is not expensive to produce and is its own best representation. Therefore after initial paper-based throw-away prototypes, the approach was to develop incremental evolutionary prototypes (Preece, Rogers & Sharp 2002), in which a simple interface was developed and elaborated, and additional functionality of logging and adaptation included in later prototypes.

This approach was in line with other researchers working with children with autism whose work was noted in Chapter 2. For example, Tartaro (2006) stressed the importance of observational studies and the iterative development of prototypes. The importance of beginning with a very simple design which is elaborated as the results of evaluative trials was stressed by Kozima et al. (2005) in the context of robot design. Finally, François et al.(2008), Robins et al. (2004), Grynspan et al. (2005; 2007), Massaro (2006), and others, all used long term evaluative trials working with children with autism.

4.4 Design criteria

The focus of concern during the design of TouchStory was on the game, that is the screen design and the software logging of on-screen interaction. The goal was to build prototypes to explore the use of the proto-narrative concept with children with autism, it was not to produce a complete system. So for example, the interface to tasks which the experimenter must carry out (setting up the t-stories, preparing for a visit, inspecting the logs) was not a focus of concern.

The design framework for TouchStory was presented in section 3.8. The overarching design criteria were that TouchStory would provide a 'good' learning environment in terms of issues discussed in section 2.6 *Play, fun and engagement in learning and narrative,* while at the same time specifically addressing the needs and preferences of children with autism as described in section 2.5 *Autism and learning*. The TouchStory design presented in this chapter is evaluated against these design criteria section 4.11.

4.5 An overview of TouchStory versions

In all there were three versions of TouchStory. An overview of all the versions is given in this section with more detailed description in the following sections.

TouchStory version 1

- This version presented picture stories of a specific format; each story was 5 pictures in length, in each case it was the middle picture that was missing.
- The layout was in a comic book style.
- There was no software logging.

TouchStory version 1 was used in trial 1 which is described in Chapter 6.

TouchStory version 2

- This version presented proto-narratives of 3, 4 or 5 pictures in length; the position of the missing picture was not fixed and could be in any position, but it was fixed for a particular t-story.
- The layout was in a single line comic strip style, illustrated in Figure 4-1.
- The on-screen activity was logged to a text file. This text file was used as the basis for adaptation.

The introduction of new t-stories was under experimental control, for example, new t-stories were introduced throughout trial 2 with about one third of the t-stories being replaced at each visit. Adaptation for this version was by hand; in trial 2 the logs were visually inspected and the adaptive formula, introduced in section 3.6, was applied manually, this process is described in section 4.8. Trial 2 is described in Chapter 7.

TouchStory version 3

- This version was the same as TouchStory version 2 except that, in addition, for each t-story answered during a session the first option docked by the player was taken to be the *intended* answer and this was logged to a database. These logs form the participant's profile which was used as the basis for adaptation.
- Two additional programs were developed:

- ‘Adapter’ which, for each participant, adapts the number of t-stories to be offered to the participant from each proto-narrative category, thus adjusting the relative proportion of each proto-narrative category in the following session. The formula takes as its basis the number of t-stories offered to the participant from each proto-narrative category in the most recent visit, and applies an adaptive formula based on each participant’s profile in the database log.
- ‘Populate’ which prepares for a school visit by, for each participant, producing a list of the t-stories which the participant is to see. Each list is based on the *number* of t-stories which that participant is to see from each proto-narrative category and is drawn from a previously constructed schedule of t-story use.

By dissociating the adaptive process from TouchStory the frequency of adaptation was under experimental control. For example, no adaptation was required in the early, information gathering, stages of trial 3. Further, during the adaptive phase of trial 3 adaptation was to be applied every *second* visit. This is elaborated in Chapter 8.

4.6 Screen design

Given the characteristics and preferences of this particular group of learners, a design imperative was to 'keep things simple', maintaining strong analogies with the concrete, physical world, and introducing features only if necessary to provide each individual child with a focussed and enjoyable game from which he or she may learn about or absorb, or become familiar with primitive components of narrative. Terminology used with respect to the TouchStory screen can be found in Figure 3-3.

4.6.1 The screen design of TouchStory version 1

The purpose of TouchStory version 1 was to trial the concept of the fill-the-gap game, together with the touch monitor as a medium for interaction. The screen was laid out with the picture narrative to the left of the screen and the options arranged vertically down the right-hand side of the screen. The picture narrative was laid out in a comic book style, with the panels to be read from left to right and then top to bottom. This layout was discussed with teachers at the participating schools, who thought it appropriate for their pupils. To provide a comfortable, reliable experience the picture stories were all five panels in length, with the middle panel being the empty one. The options could be dragged across the screen.

The player was free to move the options across the screen as part of the thinking process, an option was not considered as a chosen answer until it was docked in the in the empty panel.

4.6.2 The screen design of TouchStory versions 2 and 3

The screen design of TouchStory versions 2 and 3 differed from that of version 1 in several ways. First the fixed position of the empty panel in the middle position was too limiting; the interest was in narrative gaps at any point in the proto-narrative, therefore it was necessary to vary the position of the empty panel in different t-stories (for any one t-story the position of the empty panel did not change). In addition, to enhance generalisation, it was required that t-stories were not all 5 panels in length. With these changes the pleasing reliability and clear left to right top to bottom structure of version 1 was lost, and so a single line comic strip style layout was adopted. This required only that it be read from left to right; being a single line there was no top to bottom. Therefore, the position of the empty panel changed in only one dimension not in two, giving a greater feeling of reliability and consistency. The layout used in version 2 and 3 is shown in Figure 4-1. This layout, using only one line, placed a realistic upper limit of five panels on t-story length. The shortest t-stories used were three panels long. The figures presented here were previously published in (Davis et al. 2007b).

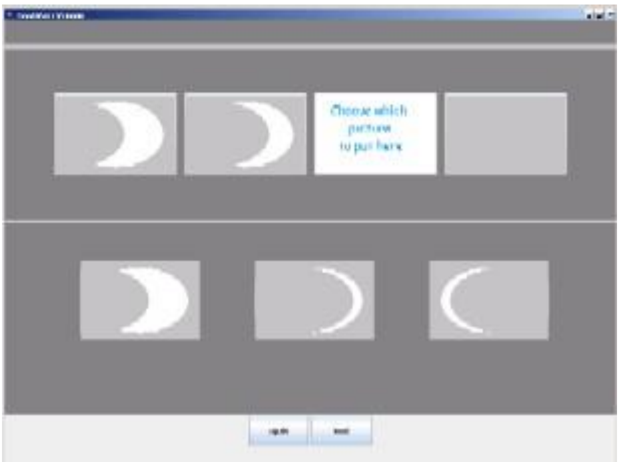


Figure 4-1 A TouchStory screen (versions 2 and 3) at the beginning of a game.

Figure 4-2 shows a screen during play, as option 2 (which is not correct) is being dragged across the screen. Recall that this is not considered an intended answer until the option is docked in the empty panel.

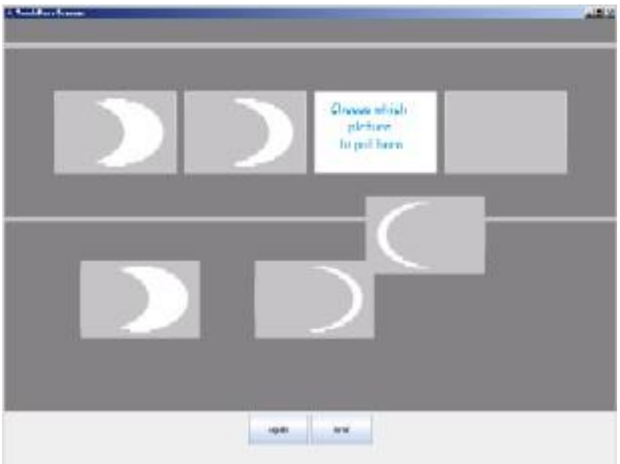


Figure 4-2 A TouchStory game in play

4.6.3 On-screen feedback

To reward a correct answer, and to enhance the feeling of closure, the correct answer becomes fixed in place and the distracters (wrong answers) disappear leaving just the complete t-story shown in Figure 4-3. This feedback and simple reward reinforce the task; the participant has the opportunity to observe the complete proto-narrative and reflect on the options available in the t-story. The participant (or person working with the participant) may select the 'again' button to revisit the t-story immediately if required, or alternatively, select the ‘next’ button to move on to the next t-story.

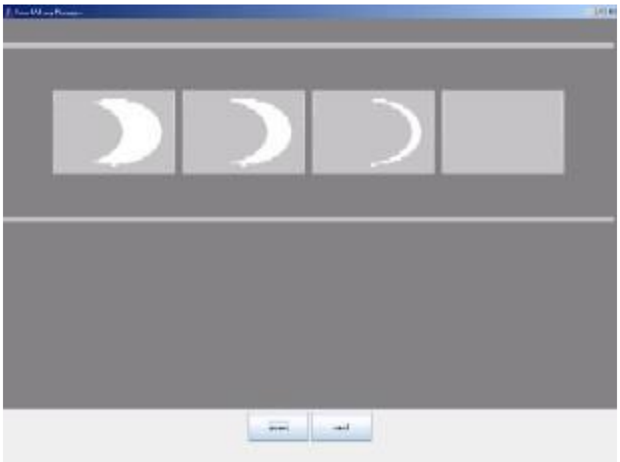


Figure 4-3 TouchStory Screen showing the reward for the correct answer

In contrast, if an incorrect option is docked, then nothing happens. Thus a wrong answer does not cause any response from TouchStory which might be found interesting and a goal in its own right. A wrong answer is shown in Figure 4-4.

At this point the participant has a number of choices;

- leave the wrong answer where it is, and either;
  - go to the next t-story using the *next* button, without docking another option.
  - dock another option 'on top of' the wrong answer.
- move the wrong answer out of the way by dragging it to some other position on the screen, and either;
  - go to the next t-story using the *next* button, without further docking.
  - dock an option; the possibility of redocking the same answer is still open.
- begin the t-story again using the *again* button.

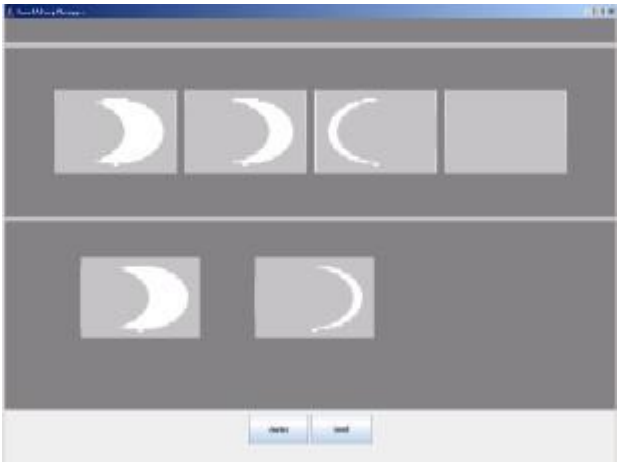


Figure 4-4 A TouchStory screen when a wrong answer is docked

To stress the point, a participant is not required to provide or even to be shown a 'right answer'. Any learning which occurs through getting the right answer by chance, or hunting down the right answer by trial and error, is self-directed curiosity-driven learning.

4.7 TouchStory in use

A number of issues became apparent while TouchStory was in use, especially during the first extended study (trial 2), these are addressed below.

4.7.1 Navigation

Inspection of Figure 3-3 shows three navigation buttons, *previous* and *next*, with their usual meanings, and *again* which resets the layout of the current t-story to the start of game layout. These are small buttons and were intended for the collaborating adult. In fact it became apparent that a number of participants did understand the use of the buttons (particularly the *next* button) and wanted to navigate for themselves. This being so, the buttons were increased in size so that they were more easily used by the child participant, and to direct the flow of the game the *previous* button was removed. The next button was made effective only once, repeated pressing had no effect. This was in part to avoid repetitive behaviours, but also to avoid accidentally skipping a t-story if the *next* button is inadvertently touched twice. In fact all that is required to reactivate the *next* button is to touch one of the options.

4.7.2 Docking

Initially, to give positive feedback of success, an attractor function was used to snap a correct answer in place once it was clearly overlapping the empty panel. However this attractor function was also applied to the distracters after the first few visits in response to a clear need; participants were observed to spend a long time trying to fit a wrong answer exactly. This was particularly frustrating for those participants experiencing difficulty dragging. It was also bringing particular attention to wrong answers, which was undesirable. The attractor function relates to Fitt's Law. There are a number of variants of Fitt's Law, the one below is taken from Dix et al. (2004, page 442), which says that the time taken to move to a target of size S from a distance D is:

$$a + b \log_2(D/S + 1)$$

where constants a and b depend on the particular pointing device in its current state, and on the skill of the user. The attractor function effectively increases S, so decreasing docking time. As it had been observed that some participants prefer to reposition a wrong answer, moving it out of the way before trying again, the distracters remain draggable once pulled into place.

4.7.3 Dragging

It became apparent during the first few visits of trial 2 that some participants were having difficulty dragging pictures on the touch-sensitive screen. This is important as observations showed that it could cause a participant to abandon one option (which might have been the correct answer) and try another. The touch monitor manufacturers were responsive but had no suggestions in addition to measures which had already been tried. The current author investigated this pragmatically by visiting the British Library which had a touch screen presentation with movable pictures as part of a display of ancient manuscripts. The same effect was found. For example, the movable object could be ‘left behind’ if the finger was dragged too quickly across the screen. It was concluded that this was a limitation of the technology. Therefore this was tackled by a variety of strategies in concert:

1. software strategies
    a. reduce redrawing to the minimum which still produces an acceptably smooth movement.
2. custom and practice strategies
    a. wipe the screen with a screen wipe after each child.
    b. wash and dry hands before using the touch screen.

The effectiveness of these strategies, together with any improvement in the child's own technique, is illustrated by Table 4-1 which shows, for one example child, the percentage of t-stories in which he experienced some mild difficulty dragging. It can be seen that by the adaptive phase (from visit 8) dragging was much improved.

Table 4-1 The percentage of T-stories in which one participant experienced dragging difficulties during trial 2

Visits	**v1-v2**	**v4-v6**	**v7-v9**	**v10-v11**
% t-stories showing mild difficulty	33	30	19.5	7.3

4.8 Adaptation

The proto-narrative approach allowed TouchStory sessions to be adapted to reflect the skills and needs of each individual participant. The purpose of the adaptation being to offer each participant a challenging set of t-stories while retaining the aspect of an enjoyable game. The adaptation was achieved by applying an adaptive formula to the participant's current *session plan*, based on the participant's recent *TouchStory profile*. These terms are explained below. A session plan shows the number of t-stories from each proto-narrative category which are to be presented to the participant in the planned session; an example is given in Table 4-2. Note that a session plan does not indicate the actual t-stories to be used or an order of presentation.

Table 4-2 An example TouchStory session plan for one participant.

proto-narrative category	**participant to see**
pnc1	4
pnc2	3
pnc3	3
pnc4	3
pnc5	1

The participant's TouchStory profile is a record of each t-story attempted by the participant and whether the given answer was correct or not. In trial 2 this profile was derived from visual inspection of the interaction logs written by the TouchStory program in conjunction with video recordings and notes taken by the experimenter during the sessions. Table 4-3 shows a fragment of a TouchStory interaction log together with explanatory comments. In this extract the participant first selected and docked option 1 which was an incorrect answer (see lines 4 – 6 in Table 4-3), then realising that this was incorrect, he moved option 1 away from the empty panel area (see lines 8 – 11), he then selected and docked option 0 which was correct (see lines 13 – 15). In building the profile, for each t-story the first picture to be docked in the empty panel was taken as the intended answer, this allowed the participant to touch or move pictures on the workspace as part of the thought process prior to moving one picture into the empty panel.

Table 4-3 Log of one participant attempting one t story

Line	**Log**	**Interpretation and comments**
1	next story eggmeal	t-story 'eggmeal'
2	time 11:36:09	is shown at time 11:36:09
3	option 1 (wrong) selected	the child selects the middle (wrong) option,
4	option 1 at 433 371	and drags it across the screen,
5	option 1 at 472 225	through these coordinates
6	option 1 fitting---------	and docks this, wrong, option in the empty panel.
7	option 1 at 482 102	
8	time 11:36:10	The child realises this is a wrong answer,
9	option 1 (wrong) selected	and, by choice, drags the option out of the way,
10	option 1 at 391 172	through these co-ordinates.
11	option 1 at 329 354	
12	time 11:36:11	
13	option 0 (correct) selected	The child now selects option 0, the leftmost one,
14	option 0 at 356 192	drags it though this coordinate,
15	option 0 fitting*********	and docks this, correct, option in the empty panel.

An overview of the adaptive process is given in Figure 4-5, and a worked example is presented later in this section. The adaptive process had two main phases. First, the production of a raw session plan (stages 1, 2 and 3 in Figure 4-5); the raw session plan is produced by adapting the participant's current session plan by applying an adaptive formula based on the participant's TouchStory profile. The effect is to tailor the number of t-stories from each proto-narrative category to the individual participant.

Second, the production of the actual new session plan from the raw session plan (process 4 in Figure 4-5); in this phase the raw session plan is conformed such that the number of t-stories in the new session plan is within a given range. The intention was to present sufficient t-stories for the participant to gain the feeling of a notable task without over-taxing the participant. This range (12-14 in trial 2) was obtained by observation of participants interacting with TouchStory prior to any adaptation being applied.

Adapting a session plan for one participant

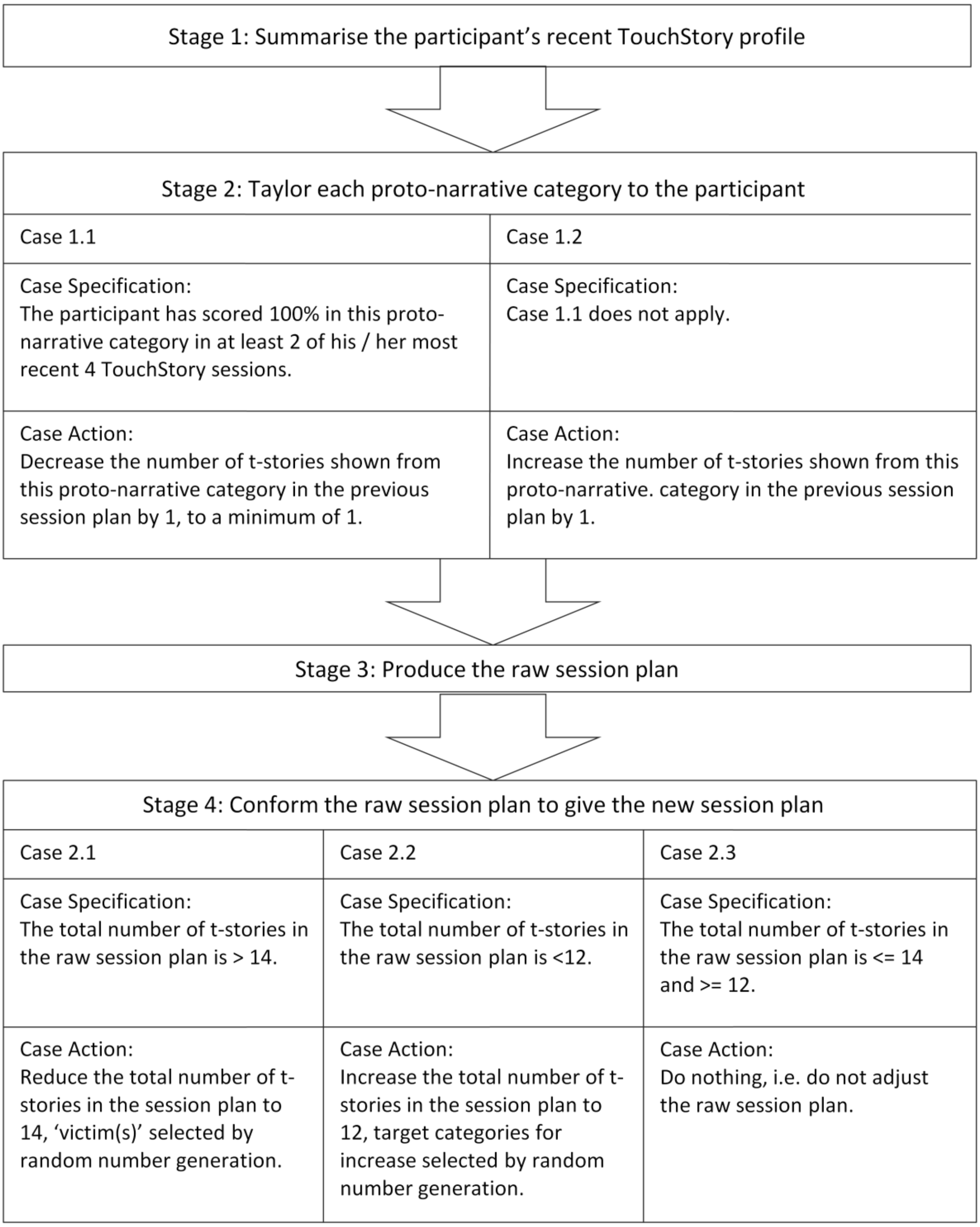


Figure 4-5 The process of adapting a session plan for one participant

A bottom-up approach was taken to the development of the adaptive formula, that being to initially evaluate a simple formula over a long term study and to increase its complexity for further studies only as indicated by the evaluation. The initial adaptive formula, used in trial 2, is shown in Figure 4-5; the evaluation of this formula and consequent changes to it are discussed as part of the discussion of trial 2 in Chapter 7.

In trial 2 the adaptation was not automated (although it was automated for trial 3), rather the formula was applied by hand between sessions. An illustrative example is given below.

This example is concerned with adapting the session plan for participant P_1 in preparation for his TouchStory session in visit V_n. Assume that the session plan given in Table 4-2 was used for participant P_1 on school visit V_{n-1}. Stage 1 of the adaptation is to summarise this participant's TouchStory profile over the participant's four most recent TouchStory sessions. This summary consists of the number of correct answers as a percentage of the number of t-stories attempted by the participant in each proto-narrative category. The session plan used on visit V_{n-1} and the participant's recent TouchStory profile leading up to visit V_n are shown in Table 4-4. The participant was absent from school on visit V_{n-3}, and so no scores are available for that visit. The columns *Applicable case* and *Raw session plan for visit V_n* are to be completed later in the example.

Table 4-4 Session plan and recent TouchStory profile for participant p1.

proto-narrative category	session plan for visit V_{n-1}	TouchStory profile as a %					Applicable case - see Figure 4-5	Raw session plan for visit V_n
		visit V_{n-5}	visit V_{n-4}	visit V_{n-3}	visit V_{n-2}	visit V_{n-1}		
pnc1	4	100	67	-	50	75		
pnc2	3	50	67	-	67	50		
pnc3	3	50	50	-	100	67		
pnc4	3	100	50	-	100	50		
pnc5	1	67	100	-	100	100		

The second stage is to apply the adaptive formula to each proto-narrative category:

- In the case of proto-narrative category pnc1, it can be seen from Figure 4-5 that case 1.2 is applicable, that is the participant had not scored 100% in this proto-narrative category on at least 2 of his last 4 TouchStory sessions. Therefore the action for case 1.2 was applied, and the number of t-stories from this proto-narrative category was increased from 4 to 5.

- Analysis for proto-narrative categories pnc2 and pnc3 was similar, and the number of t-stories to be seen in these categories was again increased by 1.
- In the case of proto-narrative category pnc4, it can be seen from Figure 4-5 that case 1.1 is applicable, that is the participant had scored 100% in this proto-narrative category in at least 2 of his last 4 TouchStory sessions. Note here the distinction between sessions and visits; the participant *had* scored 100% on at least 2 of his most recent 4 *sessions*, even though (because of absence) he had not scored 100% on at least 2 of his most recent 4 visits. Therefore the action for case 1.1 was applied and the number of t-stories to be offered was reduced from 2 to 1.
- In the case of proto-narrative category pnc5, again case 1.1 applies. However, recall that the action for this case was to reduce the number of t-stories by 1, *to a minimum of 1*. Therefore, the number of t-stories to be shown from category pnc5 remained at 1.

These outcomes are summarised in Table 4-5.

Table 4-5 Summary of the inputs and outcomes of stage 1 of a single adaptive round for one participant

proto-narrative category	session plan for visit V_{n-1}	TouchStory profile as a %					Applicable case - see Figure 4-5	Raw session plan for visit V_n
		visit V_{n-5}	visit V_{n-4}	visit V_{n-3}	visit V_{n-2}	visit V_{n-1}		
pnc1	4	100	67	-	50	75	1.2	5
pnc2	3	50	67	-	67	50	1.2	4
pnc3	3	50	50	-	100	67	1.2	4
pnc4	3	100	50	-	100	50	1.1	2
pnc5	1	67	100	-	100	100	1.1	1

Stage 3 was to combine the outcomes from stage 2; the combined effect of applying the adaptive function to each proto-narrative category being to produce the raw session plan. The next stage (Figure 4-5, stage 4), was to conform the raw session plan. The total number of t-stories in the raw session plan can be seen to be 16, therefore case 2.1 applied, that is the total number of t-stories in the raw session plan is > 14, the corresponding action being to reduce the number of t-stories to 14. Victim proto-narrative categories were selected by random number generation. The adaptation process is illustrated in Table 4-6.

Table 4-6 Summary of the inputs and outcomes of stage 2 of a single adaptive round for one participant

proto-narrative category	number of t-stories in the raw session plan for visit V_n	allotted integers	victims	count of victims identified	number of t-stories in the conformed session plan for visit V_n
pnc1	5	1,2,3,4,5	1	1	5-1 = 4
pnc2	4	6,7,8,9	9	1	4-1 = 3
pnc3	4	10,11,12,13	-	0	4-0 = 4
pnc4	2	14,15	-	0	2-0 = 2
pnc5	1	16	-	0	1-0 = 1

To reduce the number of proto-narratives in a session plan from 16 to 14, first the integers 1 to 16 were allotted among the proto-narrative categories in accordance with the raw session plan. In Table 4-6 the raw session plan has five t-stories from proto-narrative category pnc1, so five integers were allotted to this category, in this case the integers 1, 2, 3, 4 and 5, as shown in the third column of Table 4-6. Similarly, the raw session plan indicates four t-stories from proto-narrative category pnc2, so four integers were allotted to this category, these being the integers 6, 7, 8 and 9, and so on. Next two random integers with values between 1 and 16, were generated using a random number generator[2], in this example the integers 9 and 1 were generated. These identify the victim categories; the integer 1 belongs to category pnc1, and the integer 9 belongs to category pnc2, shown in the *victims* column. Both of these categories were reduced by 1, this is shown in the column *count of victims identified* in Table 4-6, all other categories remained unchanged. The resulting conformed session plan is shown in the rightmost column.

Table 4-7 shows the session plan for visit V_{n-1} together with the plan derived above for visit V_n. It can be seen the outcome of this adaptive round was to offer the participant one more

[2] http//:www.random.org

example from a proto-narrative category which was challenging (pnc3), and to reduce the number offered from a proto-narrative category in which he was doing well (pnc4).

Table 4-7 Summary the effect of one adaptive round for one participant.

proto-narrative category	**visit V_{n-1}**	**visit V_n**
pnc1	4	4
pnc2	3	3
pnc3	3	4
pnc4	3	2
pnc5	1	1

Two issues exist which did not occur in the above worked example; first, at least one t-story is always offered from each proto-narrative category. If a random number is generated which would reduce a category to zero (for example 16 in the above example), then it is discarded and another random number generated. Second, it is quite possible for the victims to belong to the same proto-narrative category, subject to the first point just mentioned. So, in the worked example, the generation of integers 10 and 13 would have caused the proto-narrative category pnc3 to be reduced by 2 to 2, however the generation of integers 14 and 15 would have caused the proto-narrative category pnc4 to be reduced by 1 to 1, and another random number to be generated.

4.9 Implementation issues

TouchStory was implemented using Java and Microsoft Access. It was developed using a normal command line interface and later the JBuilder3: University Edition IDE. The TouchStory code can be found in Appendix F. For further development of TouchStory it would be appropriate to migrate to a more modern development environment such as NetBeans. None of the code for TouchStory was automatically generated.

Details of the t-stories; the names and order of the pictures, the position of the empty panel, the names and position of the distracters and correct answer, are held in a Microsoft Access database.

Personal learning needs and approach. At the beginning of this work the author had knowledge of basic Java, and a good knowledge of database theory and practice, but no experience developing an interface with draggable features in Java. The author made use of the following book and on-line tutorials (Geary 1999; Sun 2008) and consulted a number of textbooks on various database and Java programming issues.

4.10 Production of t-stories

A number of design decisions were taken with respect to the t-stories. First, that there should be within each proto-narrative category a corpus of t-stories which were simple both in terms of content and visual complexity. The degree to which simplicity is possible depends on the proto-narrative category, for example simpler proto-narratives of lower visual complexity can be created for the background, character and reversible sequence proto-narrative categories than for the temporal or narrative sequences. Second, more visually complex t-stories would be produced to give more direct relevance to everyday life. Third, the use of images of human subjects would be avoided in the t-stories, and narrative sequences involving human characters would be taken from published sources. Thus a range of visual complexity can be found among the t-stories. Copies of all t-stories, except those from published sources, can be found in Appendix G.

There were four methods used in the production of t-stories:

- Software generated as part of the TouchStory program, such as in Figure 4-1.
- Drawn by the author using common software drawing tools.
- Scanned from published sources. The sources used were (Dodd 1986; 1987; Hunt & Brychta 1991a; 1991b; 2008).
- Digital photographs (some with graphic overlays).

With respect to the production and deployment of t-stories; trial 2 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 of working age recruited from a university. Selection was largely by convenience, although efforts were made to address some obvious pitfalls such as red/green colour blindness and dyslexia. The panel had 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 randomised for each adult, and they were asked to select the best picture to fit in the empty panel and to verbalise any observations, such as if they thought 2 or more answers, or none, could be correct. In 98 % of all cases (551/560) the picture selected by the panel member was the one expected by the author according to the answer scheme which had been previously prepared. A further 27 t-stories were prepared for trial 3. These were moderated by a similar but smaller panel of 4 men and 1 woman. Again, in most cases (132/135) the answer given agreed with the pre-defined answer scheme prepared by the author. The panels were made up of adults rather than children as the purpose was to check for mistakes and ambiguity. Further, as explained in section 2.4, typically developing children and those with general intellectual impairment are known to give qualitatively different answers to questions about narrative.

4.11 Conceptual and design issues revisited

In this section the design of TouchStory is considered in three contexts: first, Luc Steels' discussion of fun and flow in learning environments which was presented in section 2.6.1; second, the needs and preferences of children with autism as described in section 2.5 and last, the questions pertinent to the design of learning environments raised by Du Boulay which were also noted in section 2.5.

The ways in which TouchStory addresses Luc Steels' discussion of fun and flow in learning environments are shown below:

'*.....the activity itself must be challenging – otherwise there is no feeling of satisfaction after difficulties have been surmounted. Moreover there must be a steady progression in the nature and particularly the level of the challenge*' (Steels 2004, page 140).TouchStory is designed to be used over an extended period, the intention being that after an initial profile building phase the set of t-stories presented in a session is adapted to each individual child.

To provide this in a learning environment: *'A learner must be able to feel some control of the challenge level…'* (page 142). A child can accept or reject a challenge. For example after a wrong answer he or she may try again, or move on to the next t-story.

'...but at the same time the environment is crucial in generating new opportunities' (page 142). New opportunities are provided by the rolling introduction of new t-stories (about 30% are replaced every second visit) and by the adaptation previously mentioned.

'... and providing structure to the learning experience.' (page 142). Structure is provided by consistency within the game: the basic task in each t-story is the same (fill the gap), the number of options is constant, and the TouchStory game is a linear sequence of t-stories. Table 4-8 which continues on the following page, shows the ways in which TouchStory was designed with specific attention given to the needs of children with autism.

Table 4-8 How the TouchStory design meets the needs of children with autism.

Characteristics common in children with autism	**TouchStory**
Children with autism are likely to prefer predictable, structured and controlled procedures and environments and, possibly consequently, they like inanimate objects, machines and computers (Murray & Lesser 1999).	A computer version of a paper based game was developed. The design and behaviour being regular and predictable. The experimenter also strived to dress and behave in predictable ways.
Children with autism are generally thought to be highly visual thinkers and learners (Francis 2005).	T-stories are presented as pictures, with no verbal commands.
Children with autism might have little apparent understanding of joint attention or of shared points of reference such as references made to remote objects by pointing (Jordan & Powell 1995).	The game is presented using a touch-sensitive screen, allowing direct manipulation using a finger. The interface maintains strong analogies with the physical world.
Children with autism may be highly sensitive to noise, finding intolerable noise which is barely perceptible or unremarkable to others (Bogdashina 2003).	No sound features are used in the game.
Children with autism generally enjoy repetition.	This is relied on in TouchStory the sequential aspect of playing the game with some aspects of repetition is meant to provide a comfortable environment for the children. There are no features whose purpose is solely to attract and maintain attention.
Children with autism may engage in repetitive activity to the detriment of other activities (Jordan 1997).	A balance between autonomy and control was aimed for. For example, children who were able to could use a *next* button to move on to the next t-story. However repeated pressing of the *next* button had no effect.
Children with autism may not be able to use a standard keyboard or mouse (NAS 2008c).	The game is presented using a touch sensitive screen, allowing direct manipulation using a finger. A simple docking function aids the final placement of the child’s chosen answer.

Characteristics common in children with autism	TouchStory
Children with autism have a tendency to focus on particular details, that is, they tend to employ local rather than global integration (Happé 1997). Consequently a child with autism might focus exclusively on some seemingly irrelevant detail e.g. great interest might be taken in the experimenter's spectacles, or a program may be used not for its primary purpose, but for the pleasure of the accompanying noises.	The screen design was kept very simple with no extraneous features such as noises or animations which might become the focus of attention.
Children with autism may find failure very debilitating (Jordan & Powell 1995).	There is no penalty for a wrong answer. The accompanying adult may encourage another go if appropriate to the particular child at the time.

Last, this section considers the design of TouchStory in the context of the questions raised by du Boulay (2000) which were noted in Chapter 2:

- *How can we engage and motivate so they [the students] are willing to attempt to learn?*

There are three ways in which TouchStory is designed to engage and motivate the participants. First, the aim of the adaptation over successive interactions with TouchStory is to identify the skills of the participant and offer (through regular repeated application of the adaptive formula, as noted above) 'limited but gradually increasing opportunities for the expression of those skills' (Csikszentmihalyi 2000). Second, each t-story presented by TouchStory is a mini task, giving, for participants who understand the feedback, the satisfying sense of a completed activity. Third, to provide a relaxed and enjoyable context TouchStory is presented as a game.

- *How can we detect what the goals of the student are (if any)?*

It was not a design aim of TouchStory that the software should detect the goals of the participants. However the design of TouchStory was an iterative process in which development was interleaved with long term studies. Observation of interactions over the long term studies, and the goals of the participants, whether stated or inferred, were used to inform the development of TouchStory. For example, the desire to navigate for themselves was discussed in section 4.7.1 of this thesis.

- *How to maintain focus and coherence in the interaction?*

The simplicity of TouchStory and the nature of autism mean that focus is unlikely to be lost once it has been obtained. The TouchStory software keeps tight control of which t-stories are to be presented and the order of presentation. In navigating through a TouchStory session a participant may choose to repeat a t-story already answered, or may move on to the next t-story; to give clear structure and avoid repetitive behaviours participants may not navigate back through the session.

- *How to make the teacher's intentions to the learner clear?*

The intended use of TouchStory is conveyed to the participant through a demonstration given by the attending adult, and where necessary by guiding the participant’s own finger on the touch screen. This recognises both the visual learning style and difficulties with proto-imperative pointing commonly found in autism. The adult remains present throughout the session, without crowding the participant, but commenting positively and giving help if it is asked for, in the way described by Murray (see section 2.7.1 of this thesis).

- *What makes an environment educationally rich?*

TouchStory first provides a comfortable, safe and predictable environment, in which TouchStory is responsible for the selection and presentation of t-stories. Within each t-story game of a session there are the following points at which the participant may be actively engaged and have the opportunity for reflection and choice.

1. When a new t-story is presented the participant has the opportunity to reason about the current t-story and its relationships with previous t-stories. At this point the participant may actively make inferences to comprehend the t-story and construct a coherent internal proto-narrative. In this way the participant brings coherence to *one aspect*, or dimension of a fully fledged narrative. Alternatively he or she may guess, choosing the image he or she thinks most likely, or choosing an image at random, or by its position, or because some feature of the image has resonance. Last, if the t-story has been seen by the participant during a previous session, he or she might try to *remember* the right answer.
2. When an answer is docked there is the opportunity to reflect on the chosen answer in order to abstract the underlying principle. In the case that the correct answer is docked, the feedback gives the participant the opportunity to consider this correct answer for as long as he or she chooses to do so. A correct answer might be obtained through

remembering the answer to specific t-story, or even through a lucky guess; it is certainly not a goal of TouchStory that participants learn the answers to specific t-stories, however such right answers have value as the participant may generalise and infer principles from a corpus of known answers.

3. In the case of a wrong answer there is the opportunity to give another answer, repeat this cycle and reflect on the possibilities,
4. or just to move forward to the next t-story, possibly because the current t-story is not considered 'interesting'.

- *How does one choose what assistance might be helpful*?

TouchStory does not proactively render assistance to a t-story once it has been presented. A participant is able to find out the correct answer to a given t-story by exhaustive search, trying the three possible answers in turn until the correct one is found. As previously mentioned the attending adult will help if asked, and further will make suggestions if the participant is floundering.

These questions, which are difficult ones whoever the learner, are returned to in Chapter 8.

4.12 Research questions raised by TouchStory design decisions

This chapter has been concerned with the design and development of a particular vehicle for presenting proto-narratives specifically for children with autism, namely TouchStory. TouchStory presents proto-narratives as a picture sequence closure games called t-stories on a touch screen. A game is played by selecting a picture and dragging it across the surface of the screen to complete the sequence. Research question 1 (last considered in section 3.7) may now be couched in terms of TouchStory rather than interactive learning environments in general and becomes:

Research question 1: Is a simple, largely predicable interactive software system such as TouchStory, which presents proto-narratives as t-story games based on the closure of picture sequences, played by selecting a picture and dragging it across the surface of the screen to complete the sequence, appropriate for children with autism?

The component parts of research question 1 and research questions 2 - 5 do not change. However the specific development method which was used for TouchStory the adaptive formula give rise to two new research question:

Research question 6: Given the difficulties of social interaction and communication faced by children with autism and those who wish to collaborate with them; is an iterative elaboration cycle over successive long term studies an appropriate software development strategy for developing software for children with autism?

Research question 7: Can an effective adaptive formula be derived by starting simply and increasing complexity only where necessary in a trial and evaluation cycle over successive long term studies?

4.13 Chapter summary

This chapter was concerned with the design and development of the TouchStory program. A rationale was given in section 4.1 for the development of an interactive software system for children with autism which uses a touch screen as the interaction device. In particular the direct and immediate manipulation by touching with a finger was cited as particularly appropriate for children with autism in section 4.2.

A rationale was presented for the design of the TouchStory prototypes in terms of the needs of learners in general, and the needs and preferences of children with autism in particular in the remainder of the chapter. The development strategy with respect to both the user interface and the adaptive formula was explained in section 4.3 this was to trial successive prototypes with children with autism over successive long term studies. It was explained in this section why often used methods of requirements elicitation, development and evaluation and methods for involving children as design team members were not appropriate. The design criteria introduced in Chapter 2 were addressed in the context of the design of TouchStory in section 4.4, and the three versions of TouchStory were described in section 4.5.

The ways in which TouchStory was designed to appeal to children with autism were described. In particular the screen layout, the choice points afforded to participants and the feedback in the cases of correct and incorrect answers were described and illustrated in section 4.6. Issues that arose during the trials regarding the usability of the TouchStory interface were addressed in section 4.7. The structure of the software logs used in the first adaptive trial, and the adaptive formula applied to those logs was described in section 4.8. The production of t-stories was described in section 4.10. Finally, in section 4.11 TouchStory was evaluated against the design criteria raised in section 4.4, and in section

4.12 the research questions of this thesis were re-cast in terms of TouchStory design decisions.

5. CHAPTER 5: AN OVERVIEW OF THE TRIALS

The study presented in this thesis consisted of a sequence of three trials forming an iterative elaboration cycle. This chapter presents an overview of the trials, overarching aspects of the approach and methods of enquiry, and common aspects of the participants and artefacts.

5.1 The trials

The purpose of the trials was to iteratively develop an interactive software game to help children with autism improve their narrative skills. The original hypothesis for this work (presented in section 1.3), which these trials addressed, may now be expressed as a main hypothesis (hypothesis H0a) and a subsidiary hypothesis (hypothesis H0b):

Hypothesis H0a: It is possible to help children with autism to improve their narrative skills by breaking down narrative into proto-narrative components and addressing these components individually.

Hypothesis H0b: By using interactive software to present proto-narratives and logging the interaction, it becomes feasible to reflect the differing abilities of individual children with autism in understanding narrative.

The research questions to be addressed by the trials have been developed throughout the thesis reflecting the exploratory nature of this work. A complete list is given below:

Question 1: Is a simple, largely predicable interactive software system such as TouchStory, which presents proto-narratives as t-story games based on the closure of picture sequences, played by selecting a picture and dragging it across the surface of the screen to complete the sequence, appropriate for children with autism?

> 1.1: Would children with autism be able to use such a system?
>
> 1.2: Would children with autism be engaged, and enjoy using the system as intended (rather than for some other purpose)?
>
> 1.3: Would a computer-based presentation have any adverse impact when compared with a similar activity in the real world?

Question 2: Does skill with proto-narratives as t-stories reflect skill with the narratives of everyday life?

Question 3: Do children with autism, as individuals, not as a population, find some proto-narrative categories more difficult than others?

Question 4: Can an adaptive formula be developed and used to reflect individual abilities with respect to proto-narrative categories and thus address individual learning needs, given that an ordering of difficulty is not known *a priori* for any individual child, and may differ among children?

Question 5: Can children with autism learn from using such a system? In particular does learning, if any, transfer to other related tasks or indeed generalise to the real world bringing about improved skill in the comprehension and construction of the fully developed narratives encountered in everyday life?

Question 6: Given the difficulties of social interaction and communication faced by children with autism and those who wish to collaborate with them; is an iterative elaboration cycle over successive long term studies an appropriate software development strategy for developing software for children with autism?

Question 7: Can an effective adaptive formula be derived by starting with a simple formula and increasing complexity only where necessary in a trial and evaluation cycle over successive long term studies?

The study consisted of three trials. The approach taken to trial design was to plan, execute and evaluate one trial, and use this information in the design of the following trial. An overview of the resulting three trials is given in Table 5-1. In total the three trials comprised about 280 individual sessions with children with autism.

Table 5-1 An overview of the TouchStory trials

Trial	**Purpose**	**Overview**
Trial 1	To compare the TouchStory game (version 1) presented as a physical game, and as an onscreen game presented using a touch-sensitive screen.	18 participants were involved and each was seen once.
Trial 2	To evaluate the proto-narrative approach presented using TouchStory version 2, and evaluate the initial adaptive function.	12 participants were involved in the trial, which was conducted over 12 school visits. The intention was to see every participant individually at every visit. However, it was recognised that a participant might not be at school on a particular day for a variety of reasons.
Trial 3	To evaluate a revised adaptive function, in particular to investigate whether the performance of participants improves with repeated exposure to TouchStory. Version 3 was used.	6 participants were involved in the trial, which was conducted over 20 school visits. The intention was to see every participant individually at every visit. It was recognised that a participant might not be at school on a particular day for a variety of reasons.

5.2 The approach

The purpose of the trials was to evaluate the proto-narrative approach and the TouchStory software, not to assess the participants. Further, the interest was in evaluating TouchStory in a normal, kindly, ecologically valid, everyday school setting. The trials were conducted in the participants' own environment. Such contextual inquiry is particularly important given the characteristics of autism, but necessarily entails some loss of control by the experimenter over the environment. Sessions were conducted in line with the project ethos described in section 1.3.3; sessions were not time limited, and participants were not *required* to attempt or complete a task. Normal supportive pedagogic interaction was maintained with participants during sessions, including encouragement, praise and physical help as appeared appropriate to the participant at the time. Interaction with TouchStory was seen as a collaborative task, with the participant and attending adult interacting with TouchStory in the manner recommended Murray and Lesser (1999) as discussed in section 2.6.1. The approach means that, although the study was in-depth, and data rigorously collected, there are confounding factors; it was not possible to collect the highly structured and regular data obtainable under strict experimental protocols and this constrains quantitative analysis. Nevertheless, it is necessary as to do otherwise would be to answer to a different question.

Methods of inquiry: As autism is a spectrum disorder, in which individuals vary greatly in the way in which autism is expressed (Powell 1999) the participants cannot be viewed as a representative random sample from a population. Rather, each trial consisted of multiple concurrent individual case studies, from which some generalizations may be drawn. Selection was *purposeful* in the selection of schools, but *open* and *convenient* in the selection of individual cases (Mays & Pope 2000); *all* of the children who were offered by the schools as potential participants were accepted. As previously discussed a case based approach is common in assistive technology precisely because assistive technology aspires to meet additional needs, and therefore studies are often necessarily ‘small n’.

The constructionist view of narrative comprehension predicts that each listener will make inferences which establish both local and global *coherence*, and *explain* events and motivations (Graesser & Wienner-Hastings 1999). However, the characteristics of autism make merely asking for such explanations problematic: some children with autism do not have productive language; those who do speak may choose not to answer (they may 'block out' unwanted questions by singing, reciting, or merely 'being absent'). In addition children with autism have particular difficulty with 'why' and 'how' questions and have difficulty with the kind of social interaction that surrounds the asking and giving of explanations. Thus, observational methods of inquiry were preferred, including videotaping sessions and software data logging.

5.3 The schools

The trials took place in two schools, both in the south east of England.

School 1 was a resourced provision within a primary school in North London and had 12 pupils aged between 4 and 11 years having specific language and communication problems. While it was not an ‘autism unit’ *per se*, at the time of the trials 10 of the 12 children had diagnoses of, or suggestive of, autism.

School 2 was a community special school near Watford and had about 87 pupils aged between 4 and 11 years. It was a well provisioned school with a policy of welcoming researchers. The children were used to visitors coming to the school, and to being taken out of the classroom for particular individual activities.

The similarities and difference between the two schools are summarised in Table 5-2.

Table 5-2 Summary of the participating schools

School 1	**School 2**
School 1 was involved in trial 1 and trial 2.	School 2 was involved in trial 1 and trial 3.
All of the children in School 1 participated and no other children were involved.	The children were drawn from a number of classes.
Touch screens and/or interactive whiteboards were not in routine use at the time of the trials. Though the participants had some experience of an interactive white board.	Some interactive whiteboards were in use at the time of trial 1, and by trial 3 interactive whiteboards were in routine use in all classrooms, where they were used for presentation. They were not intended, or positioned, for use by children.
Sessions took place in the head of provision's office, which was made available for the trials. The room was also used to store a variety of teaching materials, and as a safe place for staff to store handbags, lunch etc. Interruptions were rare.	Sessions took place in small room which was generally available. When it was not *ad hoc* arrangements were made. There were no interruptions.

5.4 Participant details

Both schools provided details of the participants in terms of age, gender, and outline diagnosis. However there was no access to detailed diagnoses such as verbal or cognitive ability. The schools also provided brief descriptions of each participant in terms of general demeanour and behaviour patterns. These are presented locally where appropriate in later chapters.

5.5 Preliminary visits

Before the actual trials took place, both schools were visited to discuss the intended research with teachers and communication (speech and language) therapists in contact with the children, and to observe and interact with children who were potential participants. Talks with teachers established that the proposed TouchStory game was appropriately situated, that it was not obviously trivial for the participants, neither was it obviously beyond their comprehension. Recall that at the time the current author had no experiential knowledge of children with autism. Teachers confirmed that 'reading' left to right and top to bottom was a concept most participants would be familiar with; and that this was to be re-enforced not undermined. They confirmed that a simple demonstration would be the best way of conveying what was possible with TouchStory, that is, the options moved on the screen and the aim was to move 'the best' option to the empty panel. At School 1 it was possible to informally observe some of the children while they were using a variety of software products. As expected, the children seemed to enjoy using the computer products, but commonly not for the intended purpose. For example, the Clicker program which is intended as *'a writing support and multimedia tool for children of all abilities'* (Clicker 2008) was used to generate pleasing noises.

5.6 Artefacts and measures

The principal artefact used during the trials was the TouchStory program as described in Chapter 4. TouchStory version 1 being used in trial 1, version 2 in trial 2 and version 3 in trial 3. Sessions were video-recorded in addition to the TouchStory logs described in Chapter 4. To ground the TouchStory findings a narrative comprehension task (NCT) was used, which is described below.

Overview of the narrative comprehension task used in the trials

A narrative comprehension task was used to ground findings from trial 2 and trial 3 in a measure of participant's comprehension of 'real world' narrative. Recall that this work was not concerned with how well participants could read, therefore a narrative comprehension task based on picture story books was used. No measures designed specifically for children with autism were found, and so a measure designed by Paris and Paris (2003) was used, and the scoring system extended by the current author, as explained later in this section. Paris and Paris were interested in early reading achievement; in particular they considered that narrative comprehension guides the decoding of symbols during early reading. They therefore devised a narrative comprehension task using pictures from a number of wordless picture story books, which they showed to be a valid quantitative measure of young children's narrative comprehension, and which could be adapted to other picture books.

They located published picture story books and adapted them by removing unnecessary pictures to shorten the task. They note that while there are many picture books for children there are few that are both wordless and of the narrative genre. This validates the experience in the current work while developing TouchStory version 1.

Components of the narrative comprehension task include:

1. A 'picture walk', this is a familiarization phase, in which participants are invited to go though the picture story, telling the story they see.
2. Story retelling, in which participants are invited to retell the story in their own words with the picture book closed.
3. Prompted comprehension; a series of 10 questions, 5 of which were about explicit information (e.g. who was in this story?) and 5 were about implicit information, requiring inferences to be made about feelings, dialogue etc.

Paris and Paris provide questions and a scoring rubric for the book Robot-Bot-Bot by Fernando Krahn (Paris & Paris 2003).

The narrative comprehension task as used in trial 2

The book *Robot-Bot-Bot* was not obtainable, and so another book which had also been used by Paris and Paris, namely *A Boy, a Dog and a Frog,* by Mercer Mayer (1978) was used in trial 2. The questions and rubric were adapted to this book as suggested by Paris & Paris.

The story retelling task was omitted for two reasons. First, Goldman et al. (1999) found children (presumably typically developing) demonstrated greater understanding by answering questions than by story retelling, this she attributes to *'the fact that question answering places fewer processing demands on children than story retelling'*. (Goldman, O'Banion Varma & Sharp 1999, page 138). Second, advice from the schools involved was that story retelling would be a difficult concept for these children.

Paris and Paris worked with school children; they make no qualification so a typical school population is assumed, that is, predominantly typically developing. As ‘who’, ‘where’, ‘what’, ‘why’ questions are particularly difficult for children with autism, the task was adapted by the current author as follows:

The task was presented to participants by their usual speech and language therapist, and her judgment was absolute in the matter of whether the task should be terminated early, or otherwise adapted, in the best interests of the participant’s well being.

Having asked a question, e.g. 'who is in this story', she would, if necessary, use her usual techniques to try to elicit the information, the important aspect being whether the child understood the picture-story, not whether the child responded to the question as initially asked. Techniques included:

- simple rephrasing of the question,
- sentence completion; 'there was a ….' ticking off on a finger , ' and a …' ticking another finger, etc.,
- forced alternatives; 'was it a boy or a girl in this story?'
- The rubric for scoring was extended; the questions and scoring remained the same but two additional measures were used, these being the response after a simple additional prompt and the response after repeated prompting.

The sessions were video-recorded and the video sequences scored by two people scoring independently, these being the current author and the speech and language therapist who had conducted the task. Where there was a difference between the scores, the sequence was re-examined by both scorers together. Where this exposed a simple mistake, such as the scorer looking at the wrong picture, this was corrected. In the case of genuinely different scores the scorers tried to establish the cause of the difference; this being generally either a difference in interpreting the child's intention (e.g. was an utterance meant as dialogue, or not), and judging the degree of prompting. In the case of small differences in score, the scores were averaged to give the participant’s score. Details of the questions and scoring rubric can be found in Appendix D.

The narrative comprehension task as used in trial 3

The narrative comprehension task was used at three points in trial 3. Following experience in trial 2 the following changes were introduced in trial 3:

- In response to feedback from teachers in trial 2, shorter picture stories were used.
- Only one additional measure was scored (rather than the two used in trial 2), giving scores for the basic response and the response after simple additional prompting (i.e. the response after repeated prompting was not scored).
- As inter-rater reliability was shown to be high in trial 2 a moderation approach was adopted. The second scorer (the same scorer as in trial 2) scored a sample of the sessions, these being all the narratives for one participant, and all the participants for one narrative. The intention was that if that also showed good inter-rater reliability then the current

author's scores should stand for all participants; otherwise all sequences would be scored by both scorers as in trial 2. The questions and score sheets can be found in Appendix D.

5.7 Conduct of TouchStory sessions

Recall that the intention was that a supportive adult would be present and available for the participant during trial sessions. This raises a question of who the attending adult should be. While by no means universal, some children with autism do not respond to strangers, that is they tend to ignore them (Nadel et al. 2000; Robins & Dautenhahn 2006): this would indicate that the attending adult should be one already known to the child. Nevertheless, in the case of TouchStory, it was decided that the author of this thesis would be present to conduct each session for the following reasons:

- First, recall that the approach taken to developing TouchStory was very much to develop a prototype which was a vehicle for exploring the proto-narrative concept and the consequent possibilities for adaptation to individual learning needs. The usability of TouchStory from the perspective of the attending adult had not been considered.
- Second, as TouchStory is a prototype it was reasonable to suppose that software or system problems might arise during a session, which it would be possible for the author (but not a teacher or teaching assistant) to fix during the visit.
- Last, teachers, therapists and teaching assistants working with children with autism are already very busy. Staff at the schools involved were supportive, generous with their time and tolerant of inconvenience. However, it is important, not only simply as human beings, but also for the benefit of future research possibilities, not to trespass on that goodwill.

This does not mean that members of school staff were not present during sessions; participants were accompanied by a member of school staff (variously teachers, teaching assistants, or speech therapist) whenever the school thought it appropriate. In the matter of whether a session should, or should not, be terminated early, the advice of such a member of staff was always followed. In addition, members of school staff were asked to carry out the narrative comprehension task for the following reasons:

- The participants are more likely to answer an adult with whom they are familiar and comfortable

- Such professionals have a number of techniques for eliciting answers from children with autism

5.8 Analysis methodology

As previously mentioned a case study research methodology was employed in this thesis. The analysis of results was both qualitative and quantitative. Of the three types of case study described by Yin (1994, cited in Cohen 2007), that is, the exploratory, the descriptive and the explanatory, the focus in this study was on the exploratory and descriptive.

Cohen (2007), who describes case studies as being a methodological approach rather than a particular set of analysis techniques, enumerates and describes different ways in which educational case study data may be analysed. Of these the following were particularly relevant to the analysis of the TouchStory data:

- describe
- summarize
- discover patterns
- discover commonalities, differences and similarities

Results from the trials were obtained by analysis of TouchStory logs supplemented by inspection of video sequences taken during the sessions and the experimenter's notes (the experimenter being the current author). Analysis considered both the task outcomes and the process, that is, not only whether given answers were correct or not but also the demeanour and engagement of the participant and the ease of conduct of the session. In the latter context the particular focus was on whether TouchStory provided the participant with an enjoyable game which he or she was able and willing to play, as evidenced by the following analysis queries: did she or he appear to **enjoy** the game; was she or he **able** to play it as intended; and **did** she or he play it as intended. The analysis used both qualitative and quantitative measures, as described below.

5.8.1 Quantitative analysis of outcomes

Outcome-based quantitative measures were used in all three trials. Noting how well children answer particular types of question, and whether they improve with time, is of course not unusual. Such an approach to evaluating software used with children with autism can be seen in (Bosseler & Massaro 2004; Grynszpan, Martin & Nadel 2005; Massaro 2006). Measures were concerned with the use of TouchStory and also with a grounding real world narrative comprehension task:

- *Measures concerned with t-stories:* for each participant, for each t-story, it was noted whether the given answer was correct according to the predefined answer scheme moderated as explained in section 4.10. The first option to be placed into the empty panel was taken as the participant's intended answer, allowing the participant time for thought, and the opportunity to move options in the workspace as part of that thought process. These results were extracted from video sequences in trial 1, from text-based software logs in trial 2, and from database logs in trial 3, following the development of TouchStory. The ways in which these results were analysed is described for each trial in the appropriate chapter (Chapter 6 for trial 1, Chapter 7 for trial 2, and Chapter 8 for trial 3), but two points were of particular interest, these being whether the participant found some proto-narrative categories easier than other proto-narrative categories, and whether individual improvement could be detected over time.
- *Measures concerned with narrative comprehension.* The intention of these measures was to ground the findings from trial 2 and trial 3 in the participant's comprehension of picture book narratives. This used the Paris and Paris narrative comprehension task as described in section 5.6. In both trials these results were obtained by inspection of video sequences.

5.8.2 Qualitative analysis of the process

Qualitative measures relating to the participant's attitude to TouchStory and the on screen interaction process were used in all three trials. The TouchStory studies adopted a similar approach of behavioural analysis based on video-recordings as has been used previously in the Aurora project (Dautenhahn & Werry 2000; Dautenhahn & Werry 2004; Robins et al. 2004; Robins, Dautenhahn & Dubowski 2005; Robins & Dautenhahn 2006). The interest for this study was in gross behaviours (rather than any analysis of second-by-second micro-behaviours) as described below:

- did the participant seem interested
    - did he or she need to be encouraged or refocused?
    - did he or she say anything or exhibit behaviours which indicated a positive or negative view of the task?

    - did he or she exhibit self-monitoring activity such as taking time to select an option, or reconsidering (and changing) his or her answer prior to placing his or her chosen option in the empty panel?
    - did he or she indulge in behaviours which were not ‘on task’?
- did the participant appear to understand the task
    - did she or he move a picture into the empty panel (regardless of whether the answer was correct or not)?
- in the case of the touch screen
    - was he or she able to drag the movable options over the touchscreen surface?
    - if he or she experienced difficulty, was he or she able to recover control?

5.8.3 Quantitative analysis of the process

In trial 3 further analysis of the text-based TouchStory logs was introduced to provide a quantitative measure of the interaction process. There is increasing research into the potential of educational software systems to provide opportunities for detailed insights into learning processes (Cox 2007; Luckin et al. 2006; Romero et al. 2007). This might make use of application-independent third party logging software, alternatively logging may be built into the educational software from the design stage, as recommended by Cox (2007). Romero et al. (2007) discussed the capture and analysis of complex hybrid data, incorporating not only the onscreen interaction, but also video capture, allowing thinking aloud protocols to be integrated with the onscreen interaction. Romero et al. use a restricted focus viewer whereby the screen was generally somewhat blurred, being in clear focus around the mouse cursor. By recording the mouse movements they were able to record the unblurred portion of the screen and therefore, they presumed, the participant’s focus at any time.

In the case of TouchStory, while there was no general record of where the participant looked, there is a similar presumption that a participant is looking at an option which he or she is touching. Thus the TouchStory text-based logs capture not only the outcomes described above but also some aspects of the interaction process by recording the following actions, which can be seen in the log fragment shown in see Table 4-2:

- an option is touched, together with whether this is the correct answer to the t-story,

- an option is moved (the position of a continuously moving option is recorded approximately 6 times per second),
- an option is fitted into the empty panel.

The TouchStory logs are both human-readable and self-annotating, the annotations being whether a selected option is correct or not, and whether it is moved into the empty panel. Chi provided a framework for developing coding systems (Chi 1997, cited in Cox 2007), which Cox adopted for interaction log analysis. The encoding of the TouchStory text-logs conformed to Chi's framework as shown in Table 5-3. The syntax of the encoding, and further rationale, are presented where they are used in Chapter 8, section 8.6.4.

Table 5-3 Encoding TouchStory logs in the context of Chi's framework for developing coding systems

Chi's framework	**Encoding TouchStory text logs**
1. reduce or sample the protocols	t-story interaction instances where the participant touched and docked ONLY the correct answer were excluded from the analysis as no useful insights could be gained from these.
2. choose grain size	The grain size was an individual t-story interaction instance, which might include several attempts at an answer.
3. develop or choose a coding scheme	As the logs were designed to be human-readable and to relate specifically to the TouchStory context, no pre-existing coding schemes were known or expected to exist. Therefore a scheme was developed which was to encode when an option was touched, when and where it was moved, and when it was docked as an answer. Unlimited changes of selected option were encoded up to the point that an option was docked, but only up to three docking events were encoded (which in the event was sufficient) per t-story instance.
4. operationalise evidence – what counts as evidence	In the case of TouchStory text-based logs there was very little judgement required once the coding scheme was known. One issue was the case of very tiny movements, which were encoded as touching, rather than moving, the option.

5.9 Chapter Summary

This chapter provided an overview of the three trials and the research questions addressed. It described the approach taken to the three trials, the schools participating in the trials, and common procedures and artefacts, in particular the narrative comprehension task used to ground trial 2 and trial 3 in a measure of 'real world' narrative comprehension. Sessions were described as being conducted in a supportive, kindly, ecologically valid setting in which participants were not required to engage with TouchStory at all, or with particular t-stories in a session. Sessions were terminated early where the well being of the participant so indicated. The limitations of this approach in terms of possible statistical analysis were noted. The consequent experimental design and analysis methodology was described.

6. Chapter 6: Trial 1 - Contrasting the TouchStory game in physical and on-screen modes

6.1 Preamble

The purpose of trial 1, which was reported in (Davis et al. 2004), was to determine whether a touch-sensitive screen, with draggable pictures, was an appropriate interaction medium for presenting t-stories to children with autism. Participants were invited to play t-story games presented in the physical world using laminated cards and in the on-screen world using TouchStory version 1, which is described in Chapter 4.

6.2 Research questions and expectations

The hypothesis for trial 1 was first presented in (Davis et al. 2003) as follows: *"computerization will not adversely affect children's interaction with a story completion game"*. With hindsight this would be better clarified as: "computerization, using draggable pictures on a touch-sensitive screen, will not adversely affect the interaction between children with autism and a story completion game".

Note that there was no intention of evaluating a variety of interaction devices, which is an interesting but different question. Rather, a touch screen was identified *a priori* as a potential interaction device as explained in section 4.2. Thus the primary research question was whether, in this context, a touch screen programmed with draggable items is an *appropriate* interaction device for children with autism. The question has two parts.

- First, are participants *successful* in the task presented using a touch screen?
- Second, do participants find the game presented using a touch screen *enjoyable* and engaging?

That is, do issues of engagement or cognition (in terms of understanding of the task, or perceptions of the game itself) affect participants' enjoyment and success when a touch screen is used as the presentation medium?

As children with autism generally enjoy using computers (see section 2.7.1), and as the on-screen game mirrors the real world as closely as possible, allowing direct manipulation and avoiding proto-imperative reference by pointing (see section 4.2), the expectation was that participants would be at least as *engaged* and *successful* with TouchStory as with a physical t-story game, assuming that the participant has the dexterity to drag items on the touch screen. As issues of manual dexterity are not uncommon in children with autism advice was sought from teachers in contact with the participants, and their expectation was that most, if not all the participants would be able physically to drag items across the screen. In case this was not so, a variant of TouchStory version1 was prepared using buttons, rather than draggable items.

Recall from section 1.3.3 of this thesis that the intention of TouchStory is not to replace a caring adult; rather it is to provide a tool which may be used by such an adult. The intention was to treat the t-story games collaboratively, with the participant and experimenter working together. This gives rise to a secondary question which is, will the touchscreen mode of interaction adversely affect the game from the perspective of the attending adult? The impact on the attending adult (the author of this thesis) was more difficult to predict as it is somewhat subjective and at that time contact with children with autism was limited to the two visits described in section 5.5. This, then, was a more open question.

6.3 The setting and the participants

Participants were drawn from both School 2 and School 1, described in Chapter 5. Each school provided a small dedicated room which was comfortable for the participants.

18 children participated, 10 at School 1 and 8 at School 2. In total there were 13 boys (12 with autism, or statements suggestive of autism), and 5 girls (2 with autism). The participants without autism were variously diagnosed with moderate learning difficulties, complex language disorder, and general developmental delay. They were not intended as a control group, but were included for any insight that could be gained. The participants were of primary school age (which is generally 4-11 years). The exact ages of participants from School 2 are not known. At School 1 ages ranged from 4 years 10 months to 9 years 8 months.

6.4 Artefacts

TouchStory version 1 was used to present 5 narrative t-stories. As creating engaging narratives for children is not trivial, especially for children with autism where narrative may be a central problem, the t-stories were derived from published sources (Dodd 1986; 1987; 1999; Hunt & Brychta 1991a; 1991b; 2008). As the chosen sources were designed for typically developing children, their suitability was discussed with teachers and communication specialists in daily contact with the participants to ensure that the narratives were appropriate and well regarded. The chosen narratives conform to Bruner's format of narrative (see section 2.2). They all use close-to-realistic paintings, in which the facial expressions of the protagonists are simplified. All the pictures in any one game were by the same artist to avoid very obvious matching on style, palette etc. With regard to the specific t-stories presented in this trial an important question was whether they were sufficiently challenging and rewarding to engage the participants. In the opinion of teachers in contact with the participants the t-stories were broadly appropriate.

A physical version was made of four of the t-stories, using laminated cards. The touch screen and physical t-stories mirrored each other as closely as possible, matching on content, layout and background colours.

6.5 Procedures and measures

The participants were seen individually, accompanied where appropriate by a teaching assistant. Also present were the current author and another adult who helped with one of the video cameras. At School 2 the helper was a research student who was not known to the children, and who took an unobtrusive position in the room. At School 1 the helper was a member of School 1 staff as the unit head was concerned about the effect of a second unknown adult on the children.

Each child was told that he or she was being asked to help in the design of interactive software. They were invited to try the four physical t-stories implemented using the laminated cards, and then to play TouchStory, which presented the four t-stories previously seen and also a fifth previously unseen t-story. In both cases the participants were not expected to play the game alone, but rather to play the game as a collaborative task with the experimenter. The participant was allowed to handle cards in the case of the physical game, and move pictures on the screen in the TouchStory game as part of the thinking process, but once a picture was moved into the target position then this was accepted as an answer. A correct answer was rewarded with verbal praise, and in the case of TouchStory the participant also saw the on-screen reward of the distracters (alternative answers) disappearing, leaving only the complete story. If a wrong picture was chosen the participant was invited to have another go.

Recall that the purpose of this trial was to evaluate the software and touchscreen, not to assess the participants; therefore sessions were not time limited, and participants were not *required* to complete the task. Adults present were free to interact with the participant during a session. Recall from section 5.2 that this approach produces confounding factors that constrain quantitative analysis. Nevertheless, it was necessary as the interest was in the use of TouchStory in a normal, kindly, ecologically valid, everyday school setting. The mode of enquiry was by observation. The sessions were videoed using two video cameras, one being trained on the participant's face, the other on the game in progress. There was no software logging in this trial.

6.6 Results and analysis

Results were obtained by analysis of the video sequences taken during the sessions. Quantitative measures related to participants' success with t-stories, as described in section5.8.1. For each t-story, in both the onscreen and physical world versions of the game, it was recorded whether:

- the first option to be placed into the empty panel was correct or not,
- if it was wrong then whether the second option to be placed in the empty panel was correct or not.

Qualitative results relate to the demeanour and engagement of the participant and ease of conduct of the session, as described in section 5.8.2.

Both qualitative and quantitative was concerned with gross behaviours, such as selecting and placing an option as an answer, rather than with micro-behaviours requiring second-by-second analysis.

6.6.1 Quantitative results

Of the 18 participants, 6 gave correct answers to all t-stories in both on-screen and physical modes, at first attempt. A further 3 participants gave no correct answers. For one participant there was a problem with the video camera trained on the game, and so the results for this participant are not available. The results for the remaining 7 participants are given in Table 6-1, and are summarised in Table 6-2.

Table 6-1: A comparison of success with TouchStory and the physical game

Child	**TS first attempt (out of 5)**	**TS second attempt (out of 5)**	**Card first attempt (out of 4)**	**Card second attempt (out of 4)**
Child1	2	5	1	3
Child2	3	5	3	3
Child3	3	5	3	3
Child4	1	2	1	4
Child5	5	5	3	4
Child6	1	2	1	2
Child7	3	4	0	1

Table 6-2: A summary of the relative success with TouchStory and the physical game of participants Child1 to Child7

	Physical version	**TouchStory version**
% correct at first attempt	42	51
% correct at second attempt	71	80

6.6.2 Qualitative results

Sixteen of the eighteen participants were able to drag pictures across the screen after a short demonstration lasting about five seconds. The remaining two participants could drag pictures after a demonstration guiding the participant's own finger. However, it was noted that the draggable pictures do not follow a finger on the touch screen as well as they do a mouse. However, all the participants were able to accommodate this and would return to a picture if it failed to follow his or her finger. As all participants could drag successfully the backup version using buttons was never used.

Video inspection showed that all except one of the participants seemed to *enjoy* the games, that is they appeared relaxed and participated actively, and showed more enthusiasm for the on-screen TouchStory version, for example choosing to stand up in order to place answer choices. Some participants made appreciative comments such as "wow".

TouchStory made fewer demands on the experimenter, largely because, being confined to two dimensions, TouchStory presented fewer interesting diversions, such as chewing the picture-cards, 'helping' to lay them out, or piling them up on the floor.

TouchStory t-stories were completed much more quickly than those using laminated cards.

6.7 Discussion and conclusions

This trial addressed the following research question: *Is a simple, largely predicable interactive software system such as TouchStory, which presents proto-narratives as t-story games which are based on the closure of picture sequences and played by selecting a picture and dragging it across the surface of the screen to complete the sequence, appropriate for children with autism. (That is, will they be able to play the game; will they find it enjoyable and use the system as intended; and will the computer-based presentation have any adverse impact when compared with a real-world presentation?).*

The trial indicated that TouchStory does present an appropriate interaction mode for children with autism. The touch screen does not appear to have any detrimental effect on success. Overall participants were at least as successful with TouchStory as with the card based version as can be seen from Table 6-2 and the participants appeared more enthusiastic and engaged. The simple interactive interface seemed adequate to maintain engagement, as did the reward for a correct answer, indeed some participants made comments which indicated they understood that the rewards indicated a correct response.

TouchStory, without doubt, made fewer demands on the experimenter than the physical version of the game. This freed the attending adult to observe or interact with the participant. The time needed by both adult and participant is less and so TouchStory t-stories were completed much more quickly than the equivalent physical games. Thus a participant could be exposed to more t-stories in a given time, resulting in a more focussed and efficient session.

However, this trial consisted of one session per participant, in which each was exposed to 5 t-stories, it was not known whether TouchStory would remain engaging over multiple exposures. In addition the trial used only picture narratives, not proto-narratives. Therefore research question 1 was revised as follows:

Question 1: Is a simple, largely predicable interactive software system such as TouchStory, which presents proto-narratives as t-story games which are based on the closure of picture sequences and played by selecting a picture and dragging it across the surface of the screen to complete the sequence, appropriate for children with autism, and will it remain engaging over extended sessions and multiple exposures.

Overall these results were encouraging, leading to the development of TouchStory version 2 during the latter half of 2004 and a long term trial in the spring of 2005.

6.8 Chapter Summary

This chapter presented the first trial, in which TouchStory version 1 was compared with a physical version of the same game. There were 18 participants, 14 of whom had diagnoses of, or suggestive of, autism. It was found that participants were at least as *successful* with the touch screen based version of the game as with the physical version, and that all except one of the participants seemed to *enjoy* the game, in particular enjoying the on-screen version of the game. The on-screen game was considerably easier for the attending adult to manage, and participants were able to complete the tasks more quickly.

The study led to the development of TouchStory version 2 to present proto-narratives, and the development of an adaptive formula so that the focus for each child can be on re-enforcing and challenging their individual narrative ability.

7. CHAPTER 7: TRIAL 2 - EXPLORING PARTICIPANTS' COMPREHENSION OF PROTO-NARRATIVES

7.1 Preamble

The purpose of this second study, which was reported in (Davis et al. 2007a), was to determine whether the *proto-narrative concept* could form the basis of an appropriate assistive tool for individual children with autism using TouchStory version 2 as a vehicle. In particular, to explore whether as a consequence of the proto-narrative approach it becomes possible, over multiple sessions, to adapt the set of t-stories presented to each participant towards the learning zone of that participant by using a simple adaptive formula based on the participant's previous TouchStory profile. Consequently the trial was a longitudinal study of 12 visits with two main phases, visits 1 to 7 in which there was no adaptation of the set of t-stories presented to individual participants, and visits 8 to 12 in which adaptation was applied. The rationale for adaptation and the adaptive formula used are described in Chapter 3.

TouchStory version 2 is described in Chapter 4, but as an *aide memoire* an illustrative t-story is shown in Figure 7-1, below.

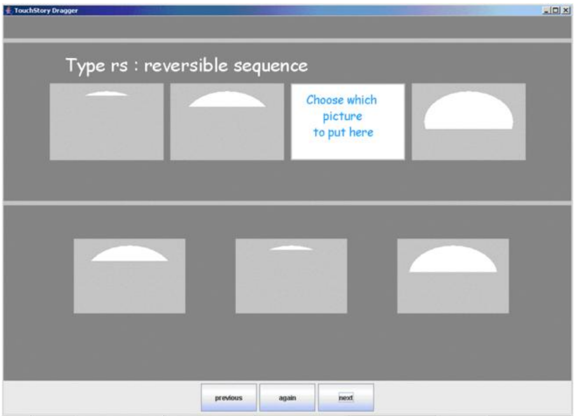


Figure 7-1 An example t-story

7.2 Research questions and expectations

The primary research question addressed by this trial was whether proto-narratives, presented using TouchStory version 2, form the basis of an *appropriate* assistive tool for individual children with autism. This question has two parts: first, does TouchStory version 2 provide an *enjoyable* game which participants are able and willing to play, and continue to do so over multiple sessions? Second, that being so, does the proto-narrative concept provide an *effective* learning tool?

Based on experience of trial 1 and the knowledge of autism which was used in the design of TouchStory, the expectations regarding the former question were as follows:

- It was expected that most participants would be *able* to play the TouchStory game when it was used to present proto-narrative tasks; that is, they would understand the task and be able to manipulate the touch screen.
- It was expected that most participants would *enjoy* TouchStory, and continue to find it engaging for longer sessions and after repeated exposure.
- It was expected that most participants would use the game as intended.

To return to the question 'does the proto-narrative concept provide an effective learning tool?' Three aspects were considered:

- Do individual participants find some proto-narrative categories more difficult than other proto-narrative categories and, if so, are there similarities among the participants?
- Does the adaptive formula gradually adapt the set of t-stories presented to individual participants over successive TouchStory sessions towards the learning zones of individual participants?
- Does success with TouchStory relate to participants' success with narrative in the real world?

Expectations with regard to these questions were as follows:

Do participants find some proto-narrative categories more difficult than other proto-narrative categories and, if so, are there similarities among the participants? Based on the work of researchers such as Tager-Flushburg and Sullivan (1995) and Happé (1997) which showed that children with autism have difficulties with specific aspects of narratives presented as picture stories and animations featuring simple shapes respectively, the expectation was that individual participants would show specific difficulties with some proto-narrative categories, but not with others. Differences between participants' TouchStory profiles were expected; the purpose of the adaptive phase being to adapt to different learning needs that could not be predicted *a priori*. Whether an ordering of difficulty, common to all participants, would be found among the proto-narrative categories was an open question but given the diversity found among children with autism, the expectation was that this would not be so. However, despite the expected diversity, it was expected that some similarities among participants' profiles would emerge.

Does the adaptive formula gradually adapt the set of t-stories presented to individual participants over successive TouchStory sessions towards the learning zones of individual participants? The adaptive formula used in this study was described in Chapter 4. The expectation was that by reducing the proportion of t-stories from categories in which the participant was already competent, the participant would begin to score less well in each session overall; but, if the participant chose to use TouchStory version 2 as an 'advisor' to find out the correct answer to t-stories which they had answered incorrectly, a gradual improvement would be seen. The expected pattern of success over an extended trial is shown schematically in Figure 7-2 no values are given as there was no firm expectation with respect to the degree of success or the time scale.

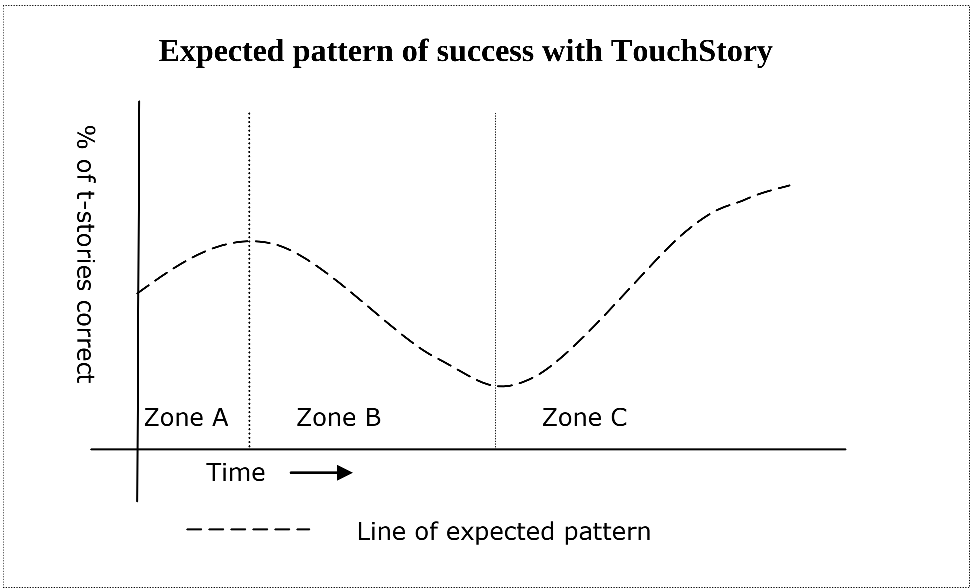


Figure 7-2. The expected pattern of success with TouchStory over an extended study in which adaptation is applied

Zone A shows an expected initial settling down period in which there are competing effects from a decline in performance as new types of t-story are introduced and an improvement in performance expected as participants become familiar with the game.

Zone B shows a decline in performance that is expected as the participant sees a gradually increasing proportion of t-stories from categories he or she finds difficult.

Zone C shows the increase in performance expected if sufficient t-stories presented within the learning zone of the participant and sufficient time was allowed for learning to take place.

Does success with TouchStory relate to participants' success with narrative in the real world? This was an open question. The expectation was that participants would find some aspects of narrative more difficult than others. While on the one hand it could be postulated that as the proto-narrative categories cover the components of narrative a correlation between success with TouchStory and success with real world narrative is to be expected. On the other hand, the whole may be more than the sum of the parts and a participant may be able to keep track of components of narrative when isolated as proto-narrative, but not be able to keep track of the various dimensions of comprehension in a complete narrative.

7.3 The setting

The trial took place at the Resourced Provision at School 1, described in Chapter 5.

7.4 The participants

All 12 children of the Resourced Provision at School 1 were involved. Ten of the twelve, all boys, were diagnosed either with autism or behaviours suggestive of autism. Recall that these children are not representatives of all children with autism, but rather they are considered as *multiple single cases*, from which some generalisations may be made. The remaining 2 children were girls, one being diagnosed with 'general developmental delay' and the other with 'social interaction difficulties'. The children were aged between 4 and 11 years. Further details are given in Table 7-1 where the column *Child* shows the details originally provided by the school for each participant, and the column *School 1 questionnaire* shows information gained from a questionnaire which is described in section 7.6. As mentioned previously there was no access to more detailed diagnoses or details of participants' verbal or cognitive ability.

Table 7-1: Participants in Trial 2

Child	**School 1 questionnaire**
ID: ch1 Gender : M Age at 1/1/05: 9;6 Statement: ASD	Enjoys using computers, has no problems with dexterity, and understands and can use a mouse. He likes stories, particularly humorous ones. He understands emotions and motives of characters at a very basic level. He does not tell imaginative stories.
ID: ch2 Gender : F Age at 1/1/05: 10;1 Statement: General developmental delay	She likes computers and can use a mouse quite well (2 on a scale 0-3, where 3 is no difficulty). She has no difficulties with manual dexterity. She does not particularly like stories. She rarely attends [to a story] enough to assess whether she understands the emotions or motives of characters. She does not tell imaginative stories.
ID: ch3 Gender: M Age at 1/1/05: 7;9 Statement: Language disorder with autistic features	He enjoys using a computer. He understands and manipulates a mouse quite well, which he learnt to do using MouseMoves (thebigbus.com). Dragging characters using a pen and interactive whiteboard had helped him see the link. He likes stories with repetitive refrains; is beginning to understand 'sad/because' at a very basic level, and not yet consistently. He does not tell imaginative stories, but loves to act out characters e.g. a policeman.
ID: ch4 Gender: M Age at 1/1/05: 10;11 Statement: ASD	Enjoys using a computer, understands and can use a mouse, and has no difficulty with manual dexterity. He quite likes stories, but prefers factual material about trains/buses/tubes. He understands the emotions and motives of characters in a story at a very basic level.
ID: ch5 Gender: M Age at 1/1/05: 10;2 Statement: difficulties lying on the autistic spectrum	He enjoys using a computer, and can use a mouse. He has some difficulties with manual dexterity (2 on 0-3 scale, above). He likes stories, particularly animal/duck stories and train stories. He seems to understand the emotions and motives of characters in stories. He likes to tell imaginative stories about trains or other characters significant to him at the time.
ID: ch6 Gender: M Age at 1/1/05: 6;11 Statement: ASD	He enjoys computers and understands and can use a mouse. He has no difficulties of manual dexterity in daily life, but has a diagnosis of mild to moderate dyspraxia, and his handwriting and scissor work are delayed. He likes all sorts of stories, and understands the emotions and motives of the characters, he is an extremely empathetic child. He likes to play and tell monster stories. No behaviours suggestive of autism have been observed at school, though they have been described at home.
ID: ch7 Gender: F Age at 1/1/05: 5;7 Statement: severe language delay, social interaction difficulties	She enjoys using a computer and is quite good at using a mouse (2 on a scale 0-3). She has excellent manual dexterity. She likes all types of story as long as they are simple. She particularly likes train and bus stories. She loves to act out shopping and baby-doll, and to retell stories several times especially Goldilocks and the Three Bears.

Child	School 1 questionnaire
ID: ch8 Gender: M Age at 1/1/05: 7;1 Statement: ASD	Does not show any evidence of enjoying computers and cannot use a mouse. He has no difficulties with manual dexterity. He does not yet have enough language to enjoy stories; he sits and appears not to listen, but can later join in repetitive refrains. He likes Thomas the Tank Engine stories but only to look at and kiss the pages. He is food obsessed and is unable to wait without crying if he sees food. He rocks in his chair.
ID: ch9 Gender: M Age at 1/1/05: 8;4 Statement: ASD + severe language disorder	He enjoys using computers, can use a mouse, and has no difficulty with manual dexterity. Language difficulties mean that he finds it hard to listen to stories, he most likes animal stories. He understands emotions at a very, very basic level (sad crying wanting mummy) related to his own needs. He will tell short stories while holding a toy, e.g. 'frog likes jumping' or 'pig is eating flies'.
ID: ch10 Gender: M Age at 1/1/05: 9;11 Statement: ASD	He likes computers, can use a mouse and has no dexterity problems. He will listen to stories. He likes series of stories, probably for the collecting element. He is beginning to understand emotions at a very basic level. He can understand sad/happy from photographs, but it is not clear that he understand emotions in stories. He retells video and story sequences to himself. He is often in his 'own world'.
ID: ch11 Gender: M Age at 1/1/05: 7;7 Statement: autistic communication disorder	He does not like computers. His ability to use a mouse is highly dependent on attention. He has considerable difficulties with manual dexterity, and is highly dyspraxic. He loves all stories, especially Thomas the Tank Engine. He likes naughty characters and can recognise sad/angry. He likes to tell stories linked to videos, but has lots of ideas of his own, although they are difficult to follow.
ID: ch12 Gender: M Age at 1/1/05: 6;0 Statement: high functioning autism	He generally likes computers and can use a mouse, which he learnt using MouseMoves. He generally has no troubles with manual dexterity in relation to computers, but is diagnosed with muscle weakness of the upper body, difficulty with fine motor skills, and difficulty with bilateral integration tasks. He likes stories about transport and with repetitive elements. He understands emotions at a very basic level. He will tell familiar stories, with prompting. He finds changes to routine difficult, and his language delay contributes to an unwillingness to participate.

7.5 Artefacts

A narrative competence task, as described in Chapter 5, was prepared for this trial based on the picture narrative book 'A Boy, A Dog and A Frog' (Meyer 1978). The questions and scoring rubric can be found in Appendix D.

7.6 Procedures and measures

The trial was a long-term study in which 12 visits were made to School 1 between February and June 2005. The participants' speech and language therapist was available during all interactions with the participants. In line with the project ethos the therapist's judgment was absolute in the matter of whether a session should be terminated early (or not) in the best interests of the child. This was important both on grounds of humanity and also to see interactions with TouchStory in an ecologically valid setting.

A number of methods were used in profiling the participants in order to ground the study in activities relevant to everyday school life. Below is a list of the methods used:

- To ground the study in day-to-day narrative comprehension, the participants were profiled using a narrative comprehension task that involved them looking at and answering questions about a picture story. The task and picture story used are described in section 5.6. This profiling took place at the beginning of the trial during the first two visits.
- So that results of the study could be seen in the context of the participant's usual abilities and behaviour patterns, members of staff were asked to complete a questionnaire about each participant. This was issued after several visits, allowing an initial rapport to develop and the questions to be formulated in the light of experience. The questionnaire can be found in Appendix C.
- TouchStory was used on all visits except the second (this omission was not by design, but because of hardware failure). TouchStory was used in two phases, the non-adaptive phase in which all participants seen on a particular day saw the same t-stories, and an adaptive phase in which the number of t-stories within each proto-narrative category was tailored to each individual participant. As described in section 4.5 new t-stories were introduced throughout the trial with about one third of the t-stories being replaced at each visit. Adaptation during this trial was by hand; the logs were visually inspected and the set of t-stories to be shown to each child was determined using an adaptive formula (see section 4.8) which was applied by hand. The adaptation was made between visits, not within the game itself. The order of presentation of t-stories was randomised in this trial. Randomization, rather than grouping of t-stories, was used to counteract any impact of position in the sequence, and to ameliorate the effects of a session being terminated early for any reason. Randomization was introduced gradually; prior to the adaptive phase t-stories were presented in proto-narrative category groups, for visit 8 randomisation was introduced within the iconic and figurative t-stories, but all the iconic t-stories were

presented before all the figurative t-stories. From visit 9 the set as a whole was presented in random order.

7.6.1 Trial timeline

The trial took place between February and June 2005. Visits were made on Fridays omitting school vacations and other inappropriate times. The trial timeline is shown in Table 7-2.

Table 7-2: Trial 2 Timeline

Phase	Visit	TouchStory	Other
Settling	v1	Introduced	NCT (for some participants, as their time permitted)
Settling	v2	Not used due to technical problems	NCT (for remaining participants)
Settled pre-adaptive	v3	Used but no adaptation applied	None
Settled pre-adaptive	v4	Used but no adaptation applied	None
Settled pre-adaptive	v5	Used but no adaptation applied	None
Settled pre-adaptive	v6	Used but no adaptation applied	None
Settled pre-adaptive	v7	Used but no adaptation applied	None
Adaptive	v8	Adapted for individuals	None
Adaptive	v9	Adapted for individuals	None
Adaptive	v10	Adapted for individuals	None
Adaptive	v11	Adapted for individuals	None
Adaptive	v12	Adapted for individuals	None

7.6.2 Measures used

The method of enquiry was by observation. Three recording methods were used as follows:

- *Video recording.* One camera was used which gave a side view of the participant, capturing the participant's general stance and attitude and interaction with the screen. Some facial expression was captured, but not eye gaze.
- *Logs of participants' interaction with the screen***.** One such log was written for each participant/ session. These were text files and record, for each t-story instance completed by the participant, each answer choice touched or moved across the screen, the positions the choice was moved through, whether the choice was correct, and whether the participant docked the choice.

- *Session notes.* These notes were made during the sessions by the experimenter to keep a register of absences of participants and a note of remarkable events regarding problems encountered, and the attitude and well being of participants.

The analysis methodology included both qualitative and quantitative measures. The quantitative measures were outcome based, as follows:

- *TouchStory*: for each t-story in each session it was noted from the TouchStory log whether the participant's first answer docked in the empty panel was correct or not. As shown in Table 4-3 the TouchStory log is human-readable and self-annotating, there is then no matter of judgement involved in extracting this measure from the TouchStory logs. This measure is the same as used for trial 1, but the information was extracted from software logs rather than video recordings.
- *Narrative comprehension task*: The scoring of this task was by inspection of video-recordings and was scored independently by two scorers. The task, questions which the participants were asked, and the score sheets were described in section 5.6.

The qualitative observations were concerned with process rather than outcomes and related to the demeanour and engagement of the participants and ease with which the sessions were conducted. The quantitative measures used in the trial are shown in Table 7-3.

Table 7-3: Measures used in trial 2.

Measure ID/ source	Measure used per participant	Reason
Pm1/ text logs	For each proto-narrative category, over the whole study, the number of t-stories answered correctly as a percentage of the number seen by that participant.	To summarise the similarities and differences among the categories and between the participants.
Pm2/ text logs	For each proto-narrative category, the proportion of t-stories answered correctly in the settled non-adaptive and the adaptive phases of the study	To summarise the effects of adaptation on success with the different proto-narrative categories for each participant.
Pm3/video sequences	Scoring for the narrative comprehension task, according to the previously defined answer scheme.	To relate success with TouchStory to success with the real world. That is to see whether there is any correlation, or whether they would seem to be measuring different things.

7.7 Results and analysis

Some of the graphs and figures used in this chapter were published in (Davis et al. 2007a).

7.7.1 Qualitative observations

These observations pertain to the research question '*does TouchStory version 2 provide an enjoyable game which participants are able and willing to play, and to continue to do so over multiple exposures?*' These results are derived from the video records and notes taken at the time.

First, did participants enjoy using TouchStory? Did it provide a comfortable, engaging experience? Most participants (9 out of 12) appeared to enjoy TouchStory sessions, that is they came willingly to the room and engaged with the activity; some made positive comments. The participants became more confident in using the touchscreen and playing the game as the trial progressed, to the extent that it was sometimes difficult to begin recording before the participants began playing the game. There was no evidence from outward behaviour that participants found the adaptive phase debilitating (recall that in the adaptive phase they were presented with a greater number of t-stories of categories they found difficult, and that failure and feedback must be handled particularly sensitively for children with autism). It would be excessive to claim that all participants were deeply immersed in TouchStory every session, but overall their attitude was positive. Of the remaining participants, one (who had enjoyed TouchStory during the exploratory study) was not happy to co-operate and would only attempt the game in the company of a specific adult. Another found it very difficult to focus on anything other than his current area of specific interest, in particular he was interested in food. For example one session was terminated when he spotted a banana which had been left in the room by a member of staff. The third participant (not diagnosed with autism) sometimes needed coaxing to participate; this was a typical behaviour for this participant.

Second, were the participants able to play the game as intended; that is, was it within their attention span, did they understand the task, were they able to use the touchscreen? The anwers are mostly 'yes'. The participants did appear to understand the task at least to some degree, and conceptually to understand the touchscreen. Two participants had particular difficulty dragging pictures across the screen with a finger, in the sense that the picture did not follow the finger (despite rigorous cleaning of hands and screen). This was important as when one picture failed to move as expected the participant would frequently abandon their first choice and try another. Most participants were engaged for each full session, however some sessions were stopped early because the participant had lost focus or was upset.

Last, did participants use TouchStory as intended? For the most part they did; they appeared, though their general behaviour and comments they made, to be focussed on the game and trying to get the correct answer at first attempt. However four occurrences of non-intended use were noted. One participant found it diffcult to resist selecting a picture if it was pink, for example a pink shape. Another participant who particularly enjoyed TouchStory took great pleasure in docking any picture, and in the early visits did not concentrate on selecting the correct picture to dock. In later visits he did think more carefully about the selection process. A third participant briefly made his own game, moving the two incorrect answers into the empty panel (see Figure 3-3) before moving the correct one, shouting 'wrong', 'wrong', 'right'. Finally, with regard to the t-stories themselves, one *incorrect* answer option in one t-story, was a very popular choice. This was a picture of the experimenter's cat and it is possible the experimenter fell into the trap of making one answer option more attractive than the others.

7.7.2 TouchStory profiles

The results presented in this section pertain to the following research questions:

- Do participants find some proto-narrative categories more difficult than other proto-narrative categories and, if so, are there similarities among the participants?
- Does the adaptive formula applied iteratively over a number of sessions gradually adapt the set of t-stories presented to individual participants towards the learning zones of the individual children?

The results showed similarities and differences among the categories and between participants, which are illustrated by summary results in Table 7-4.

Table 7-4. A summary of similarities and differences among the categories and between participants: showing for each category, over the whole study, the total number of t-stories correct as a percentage of the number seen by that participant.

proto-narrative category	**ch1**	**ch2**	**ch3**	**ch4**	**ch5**	**ch6**	**ch7**	**ch8**	**ch9**	**ch10**	**ch11**	**ch12**
b	100	67	70	100	100	91	100	78	92	100	50	64
c	100	77	64	100	100	100	100	100	100	100	45	80
ns	62	35	30	29	100	71	73	62	48	60	25	67
rs	72	41	47	54	95	57	80	27	70	73	48	38
ss	67	67	75	83	89	100	100	43	78	100	78	50
ts	25	36	31	8	88	55	100	67	32	50	60	0

Category code ‘b’ refers to background sequences; ‘c’ refers to character sequences; ‘ns’ refers to narrative sequences; ‘rs’ to reversible sequences; ‘ss’ to reversible sequences which focuds on size; and ‘ts’ refers to temporal sequences.

As the adaptive phase means that the number of t-stories shown in each category differs from participant to participant, the results show the total number of t-stories correct at first attempt as a percentage of the number seen by that participant. Consider participant ch4, there is a clear distinction between the t-story categories 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. By comparison participants ch2 and ch3, who do not have diagnoses of autism or behaviours suggestive of autism, have less differentiated profiles.

Overall longitudinal results: Recall that the expectation was that in the non-adaptive phase there would be a variety of outcomes due to the competing effects of increasing familiarity and confidence with TouchStory, and the introduction of new t-stories and t-story categories.

In the adaptive phase an initial decline was expected as participants were exposed to a higher proportion of t-stories they found difficult. In a longer study an eventual upturn would be seen if learning took place. Figure 7-3 shows the cumulative performance for each participant throughout the longitudinal study, and the effect of the adaptation by showing, for each participant, the percentage of t-stories correct considering all t-stories attempted by the participant up to the numbered visit; thus column to7 shows the percentage of correct answers up to and including visit 7 etc.

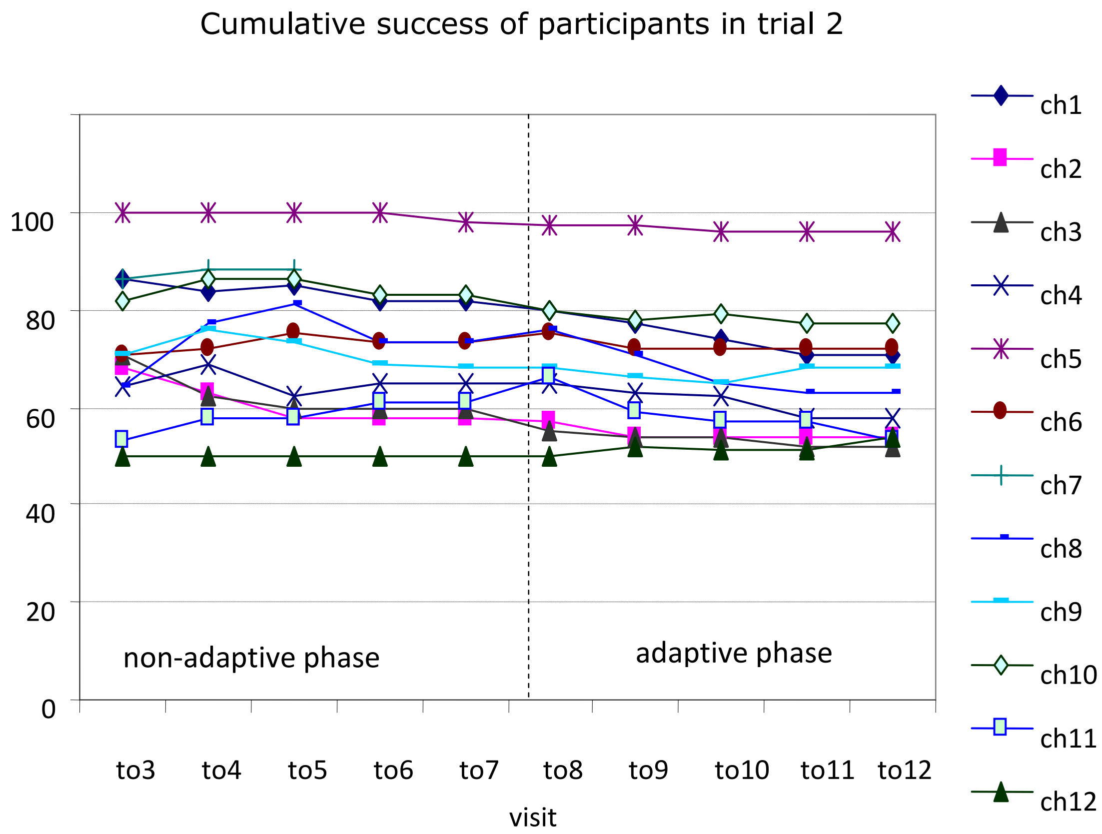


Figure 7-3 Percentage of TouchStory answers correct over all categories for each participant as the study progresses

The graph shows the expected downturn during the adaptive phase for several participants, especially those who show a clear and focussed deficit in Table 7-4 such as participants ch1, ch4, ch5, ch8, ch10. The upturn for participant ch9 is attributed to an increased interest in getting the right answer rather than an improvement in his understanding of proto-narratives.

Longitudinal results for proto-narrative categories: In this section, for each participant, results obtained for each proto-narrative category in the settled non-adaptive phase are compared with those obtained in the adaptive phase. Results are presented individually (i.e. the results are considered as many ‘single-cases’). However, to aid comparison and simplify the discussion, the results are presented in the three broad groups, these being: first, participants who did have a diagnosis of, or suggestive of, autism and who were able to participate fully in the trial as intended; second, participants who did not have a diagnosis of autism; third, participants who did have a diagnosis of autism but who, for various reasons answered a reduced set of t-stories (the specific reasons are presented with the individual’s results later in this section).

The first group consists of participants ch1, ch9, ch4, ch6, ch10 and ch5. These participants showed complete mastery of some of the proto-narrative categories and all showed least ability with temporal proto-narratives. Each participant in this group (all boys) was highly engaged with his TouchStory sessions; that is, the participant came willingly to each TouchStory session, remained focused on the session for its duration, and in some cases made positive comments. Participants ch10 and ch6 were highly competent with background and character t-stories and with t-stories based on sequences of size. Graphs are shown for these two participantsin Figure 7-4.

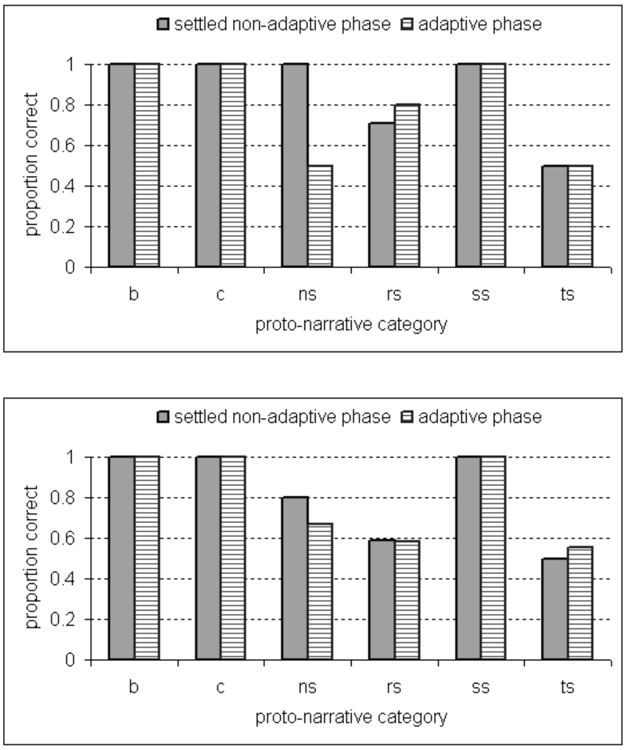


Figure 7-4. Graphs for participant ch10 (top) and ch6 (bottom) showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study.

Participants ch1 and ch9 were highly competent with background and character t-stories, and did least well with the temporal sequences; they differed from the two participants as shown in Figure 7-5 in that they were less successful with proto-narratives which were sequences based on size.

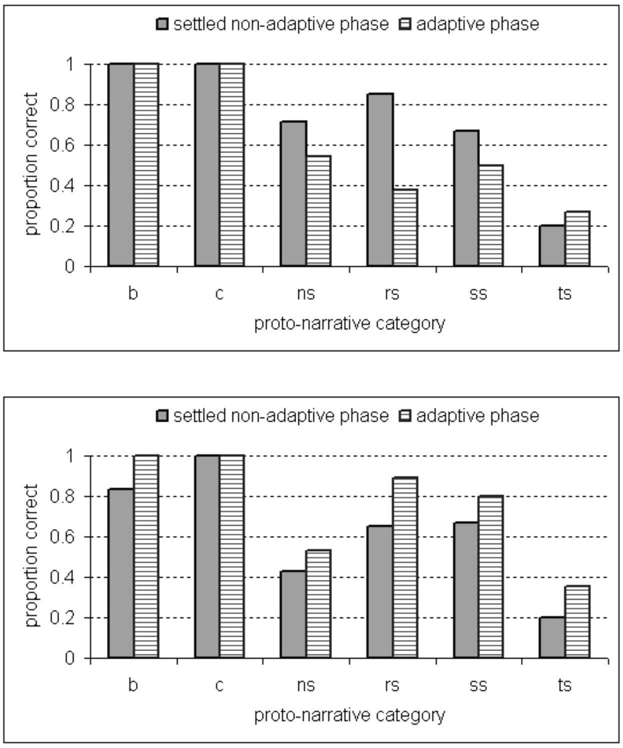


Figure 7-5. Graphs for participant ch1 (top) and ch9 (bottom) showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study.

Participant ch4 also had a similar profile, but there was a greater distinction between those categories in which he was highly successful and the temporal proto-narrative category which he found the most difficult. This is shown in Figure 7-6.

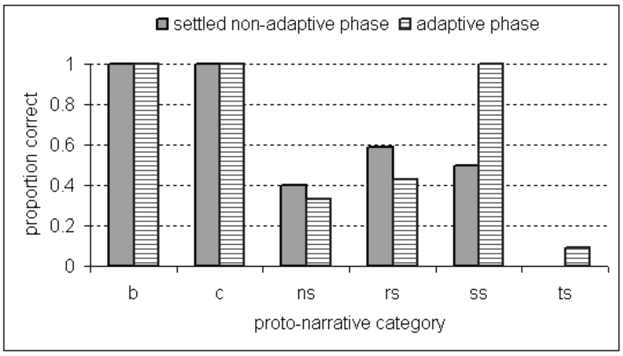


Figure 7-6. Graph for participant ch4 showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study.

Lastly in this group consider participant ch5. He was highly successful with TouchStory, as shown in Figure 7-7, however he did not find it easy; getting the right answer was very important to this participant, and he took great care considering his answers.

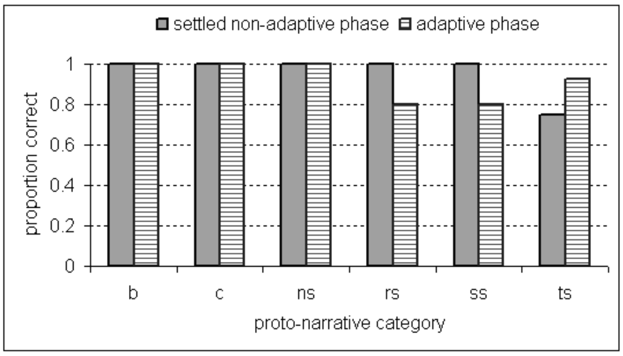


Figure 7-7. Graph for participant ch5 showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study.

Turning now to the second group, that is participants ch2 and ch3 who did not have diagnoses of autism. Figure 7-8 shows for each proto-narrative category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study by these two participants. It can be seen that, in contrast to the previous group, these profiles did not show high differentiation among proto-narrative categories; although the participants were more successful with background, character and size-sequence proto-narratives than with the remaining proto-narrative categories, there was not such a marked distinction. These participants did least well with the narrative category, in which they may have been improving. A longer study would be necessary to establish whether any genuine learning had taken place.

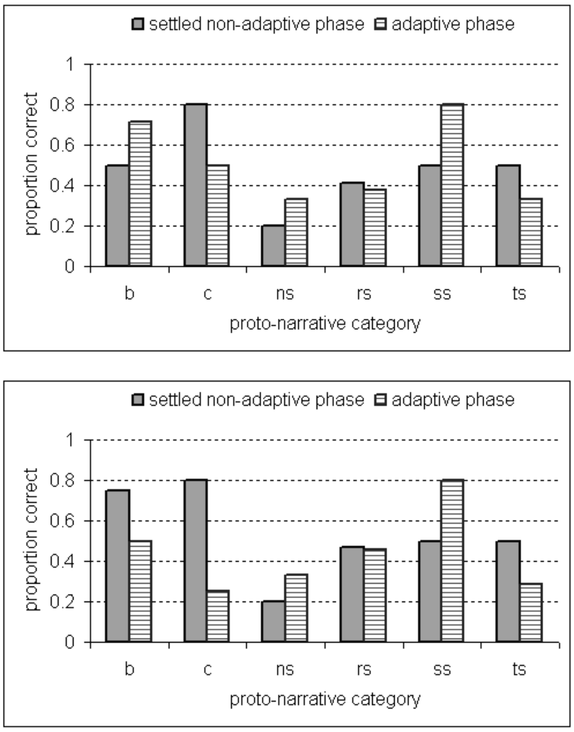


Figure 7-8. Graphs for participant ch2 (top) and ch3 (bottom) showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study.

The final group consists of those participants ch11, ch8, ch 12 and ch7. To consider first the two participants ch11 and ch8, for both these participants some sessions were terminated before all the t-stories had been attempted. In the case of participant ch11 this was because he sometimes had difficulty dragging pictures over the screen. In the case of participant ch8 this was because it was difficult to engage and maintain his attention. In both cases the behaviours were typical of the participants. The results for these participants are presented in Figure 7-9. The profiles do not show the clear distinction among proto-narrative categories seen in the first group. However, these participants attempted very few t-stories, both answering correctly an average of 5 t-stories per session.

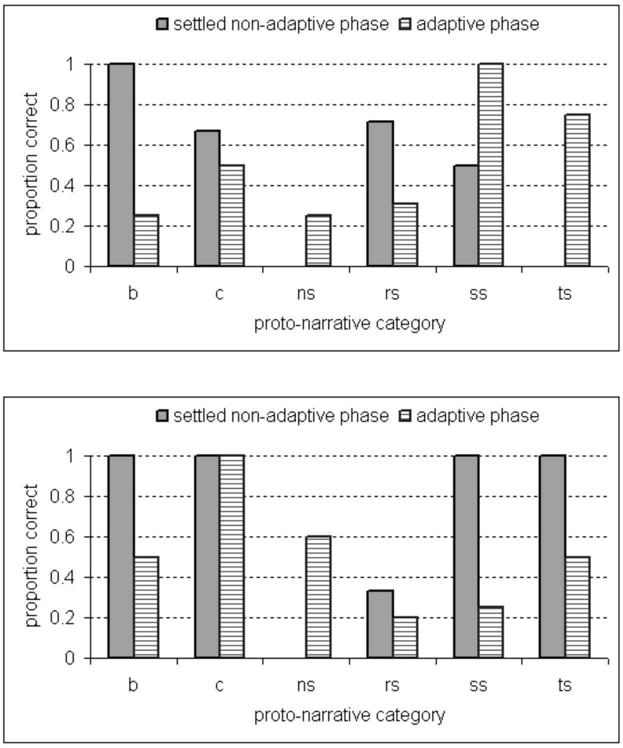


Figure 7-9. Graph for participant ch11 (top) and ch8 (bottom) showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study.

Results for participant ch12 are shown in Figure 7-10. He was initially not happy to co-operate in the study, but became more willing as the study progressed. Thus there were very few correct answers in the settled non-adaptive phase and the increase in correct answers seen in the adaptive phase represents an increased willingness to interact with TouchStory, rather than, necessarily, any improvement in his abilities with proto-narratives.

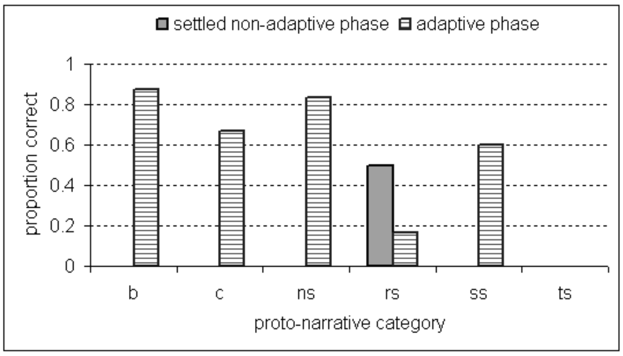


Figure 7-10 Graph for participant ch12 showing for each category the proportion of t-stories answered correctly in the settled non-adaptive and adaptive phases of the study

Results are not shown for participant ch7 as he left the provision after visit 5 to rejoin mainstream schooling. He enjoyed stories and appeared to understand the motivations and emotions of the characters. He scored very highly in the narrative comprehension task, and, as can be seen from Table 7-4, scored highly with TouchStory.

7.7.3 A comparison of TouchStory and narrative comprehension profiles

The results presented in this section pertain to the research question: 'Does success with TouchStory relate to participants' success with narrative in the real world?'

Relating TouchStory results to real world abilities. 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. The NCT scores given by the two scorers correlate using Spearman rank order correlation, as follows: r (12) = 0.96, $p<0.05$. The average score given by the two scorers was taken as the participant's NCT score. Participant ch7, who left the provision to join mainstream schooling, had the highest NCT score with 18.5 out of a possible 20. The group of participants ch1, ch9, ch4, ch6, ch10 and ch5 who have clearly differentiated profiles have NCT scores in the range 3 to 8.5 out of a possible 20. The remaining participants, with less differentiated profiles have lower NCT scores, in the range zero to 2.5 out of a possible 20.

The average number of t-stories correctly answered at first attempt, per visit, was taken as a measure of the participant's overall success with TouchStory (the TS score). The NCT scores and TS scores were found to correlate significantly at r (12) = 0.82, $p<0.05$.

7.8 Discussion of results from trial 2

Although the correlation between the narrative comprehension task and TouchStory outcomes might relate to more general issues of competence and compliance, the results are encouraging. Several participants show a clear and sustained differentiation in skill among the proto-narrative categories. While no evidence of learning was observed, the results support the view that the proto-narrative approach, together with adaptation to individual learning needs, provides a promising way forward.

Some participants, who appeared highly engaged, did less well in the adaptive phase than in the settled non-adaptive phase *within* proto-narrative categories. This was not expected. While this could be a consequence of external factors, it could be a consequence of the debilitating effect of the increased challenge, or that the randomised order of presentation made the TouchStory game less predictable and comfortable. This impacted the design of TouchStory version 3, in that the order of presentation was controlled rather than randomised in both the non-adaptive and adaptive phases, giving a more predictable and comfortable session for children with autism.

7.9 Rethinking the adaptive formula

The approach to adaptation was to evaluate a simple adaptive formula and increase the complexity of the formula as necessary. The results show that it is robust against a child having an ‘off-day' and making occasional mistakes. Atypical wrong answers were seen in the profiles of several participants, but because the adaptive formula requires 100% correct answers in only 2 of the most recent 4 sessions, occasional wrong answers have no effect. It is not robust in the case of a participant who consistently and atypically gets one particular t-story wrong (i.e. for which they see another solution). This would reduce the outcome for that proto-narrative category to less than 100% every visit it was offered.

The formula distinguishes between those proto-narrative categories in which a participant is very skilful, and those in which he or she is not skilful. It does not distinguish in the case of a participant who does have differential skills across proto-narrative categories, but does not have the high level of skill required to score 100% on two or more occasions out of the previous four in any proto-narrative category. In such cases stochastic effects are high and the adaptation unfocussed.

It was therefore proposed to increase the complexity of the adaptive formula, such that it focussed on proto-narrative categories in which the participant had some skill. The formula was developed as follows:

- If, for the proto-narrative category, the participant has scored 100% on at least 2 of the last 4 occasions, then *decrease* by 1 the number to be shown in that category, to a minimum of 1.
- If the above does not apply, but the participant has scored 50% or above on at least 2 of the last 4 occasions, then *increase* by 1 the number to be shown in that category.
- Otherwise do nothing.
- Then the profile is adjusted to present 15 t-stories, according to random numbers generated in proportion to the profile generated by application of the formula.

Stage 1: Summarise the participant's recent TouchStory profile

↓

Stage 2: Taylor each proto-narrative category to the participant		
Case 1.1	Case 1.2	Case 1.3
Case Specification: The participant has scored 100% in this proto-narrative category in at least 2 of his / her most recent 4 TouchStory sessions.	Case Specification: Case 1.1 does not apply, but the participant has scored 50% or more in this proto-narrative category in at least 2 of his / her most recent 4 TouchStory sessions.	Case Specification: Otherwise (i.e. neither case 1.1 or 1.2 apply).
Case Action: Decrease the number of t-stories shown from this proto-narrative category in the previous session plan by 1, to a minimum of 1.	Case Action: Increase the number of t-stories shown from this proto-narrative. category in the previous session plan by 1.	Case Action: Do nothing.

↓

Stage 3: Produce the raw session plan

↓

Stage 4: Conform the raw session plan to give the new session plan		
Case 2.1	Case 2.2	Case 2.3
Case Specification: The total number of t-stories in the raw session plan is > 15.	Case Specification: The total number of t-stories in the raw session plan is <15.	Case Specification: The total number of t-stories in the raw session plan = 15.
Case Action: Reduce the total number of t-stories in the session plan to 15, 'victim(s)' selected by random number generation.	Case Action: Increase the total number of t-stories in the session plan to 15, target categories for increase selected by random number generation.	Case Action: Do nothing, i.e. do not adjust the raw session plan.

Figure 7-11 The process of adapting a session plan for one participant (as revised following trial 2).

This revised process for adaptation is illustrated in Figure 7-11, which is a revised version of Figure 4-5. That is, the overall aim of the formula was to focus, not just on those categories the participant needed to practice but in the participant's zone of proximal development.

7.10 Addressing the research questions

The following research questions were addressed in this trial:

Research question 1 (as revised in Chapter 6): Is a simple, largely predicable interactive software system such as TouchStory, which presents proto-narratives as t-story games which are based on the closure of picture sequences and played by selecting a picture and dragging it across the surface of the screen to complete the sequence, appropriate for children with autism, and will it remain engaging over extended sessions and multiple exposures. It was found that TouchStory did remain engaging over extended sessions and multiple exposures.

Research question 2: Does skill with proto-narratives reflect skill with the narratives of everyday life? Overall skill with TouchStory was shown to correlate with understanding of picture narrative in the real world.

Research question 3: Do children with autism, as individuals, not as a population, find some proto-narrative categories more difficult than others? A clear distinction was found for some participants.

Research question 4: Can an adaptive formula be developed and used to reflect individual abilities with respect to proto-narrative categories and thus address individual learning needs, given that an ordering of difficulty is not known a priori for any individual child, and may differ among children? Over four adaptive cycles (visit 8 to visit 11) the adaptive formula tailored the t-stories seen towards the learning needs of those participants who were able in some categories but needed to practice others. It was less effective for other participants as described previously, a second version was described in this chapter.

Research question 5: Can children with autism learn from using such a system? No evidence of learning was seen.

The second part of research question 5 (i.e. *In particular does learning, if any, transfer to other related tasks or indeed generalise to the real world bringing about improved skill in* *the comprehension and construction of the fully developed narratives encountered in everyday life*) was not addressed in this trial.

Hypotheses were developed from these research finding and are presented at the beginning of Chapter 8.

7.11 Conclusions

The overall aim of this work was 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.

The results from trial 2 show that TouchStory, although a prototype, already goes some way towards identifying aspects of narrative which individual children find difficult. However no evidence of learning was observed in the trial.

In the light of experience in trial 2 the adaptive formula was adjusted, the aim being to find a balance between presenting sufficient t-stories from proto-narrative categories in the participant's learning zone to provide a rich learning experience, while still presenting sufficient numbers from t-story categories that the participant is able to master well, in order to maintain a comfortable, enjoyable and rewarding context.

In order to maximise the possibility of learning occurring, the third trial was planned to be a longer study. The predictability of a TouchStory session was increased by a more controlled order of presentation of t-stories according to their proto-narrative category and visual complexity, and the rate of adaptation was decreased to every second visit during the adaptive phase.

7.12 Chapter Summary

Trial 2, which comprised 12 sessions with each of 12 subjects, has been described.

The main results reported in the chapter were as follows:

- It was found that the proto-narrative approach presented by TouchStory did identify those aspects of narrative which individual participants found difficult and those in which he or she was skilled.

- Success with TouchStory over the whole trial was found to correlate with success in the narrative comprehension task.
- The adaptive formula was found to distinguish between those proto-narrative categories in which a participant was skilful and those he or she needed to practice. However, in the case of a participant needing practice in many proto-narrative categories there was no adaptation to the participant's relative success with the various proto-narrative categories in selecting which of the many to offer.
- However no evidence of learning though TouchStory was observed in the trial results.

The evaluation and enhancement of the adaptive formula was described and a longer study was designed. The experimental design of trial 3 was constructed to detect small amounts of learning.

8. CHAPTER 8: TRIAL 3 - IS TOUCHSTORY ASSISTIVE?

The overall purpose of this third study was to determine whether TouchStory version 3 provides the basis of an appropriate assistive tool for individual children with autism.

Recall that findings from trial 2 showed that the learning needs of individual participants could be identified with respect to proto-narratives. Further it was shown that, as a consequence of the proto-narrative approach, it becomes possible, over multiple exposures, to adapt the set of t-stories presented towards the learning needs of individual participants by using a simple adaptive formula. However, no evidence of learning *per se* was seen in trial 2. This led to evaluation and reconsideration of the adaptive formula, the length of the trial and the presentation order of the t-stories in a session, as discussed in Chapter 7.

Thus, the specific purpose of trial 3 was to determine whether, by modifying the adaptive formula based on experience in trial 2, and by running a longer trial (increasing from 12 visits in trial 2 to 20 in trial 3), it is possible to adapt the set of t-stories presented towards the *learning zone* of individual participants sufficiently for learning to occur.

A description of TouchStory version 3 can be found in Chapter 4.

8.1 Hypotheses and research questions

Based on observations from trials 1 and 2, the proposition for this thesis can be now be expressed as four simpler hypotheses and an outstanding open research question. Trials 1 and 2 together gave evidence for the following hypotheses:

Hypothesis 1: A simple and largely predictable interactive software system such as TouchStory, presented using a touch screen with draggable pictures, is appropriate for children with autism;

Hypothesis 2: Children with autism, who are able and willing to use TouchStory, will find some proto-narrative categories more challenging than others;

Hypothesis 3: Over multiple exposures, repeated application of a simple adaptive formula based on a participant's previous success will tailor the set of t-stories presented by TouchStory towards the learning needs of that individual participant;

Hypothesis 4: Participants' overall success with TouchStory relates to their comprehension of real world narratives presented as picture stories.

Open research question: Can children with autism learn from using such a system? In particular does learning, if any, transfer to other related tasks or indeed generalise to the real world bringing about improved skill in the comprehension and construction of the fully developed narratives encountered in everyday life?

8.2 The setting

The study took place at School 2, described in Chapter 5, during the spring and summer terms of 2007. Most sessions took place in a small room, called a green room, otherwise used for storage, as a time-out room, and for other individual activities. On the occasions when the school needed this room, *ad hoc* arrangements were made using the best space available at the time, these being an empty classroom, an alternate green room, and a staff common room.

8.3 The participants

The six participants, 5 boys and 1 girl were all pupils of School 2, aged between 6 years 6 months and 9 years 8 months at the beginning of the study. The school uses the Childhood Autism Rating Scale (CARS), on which a score of 30 or more out of a possible 60 points indicates autism. Table 8-1 presents details of the participants provided by respective class teachers. As mentioned previously, there was no access to more detailed diagnoses, verbal or cognitive abilities, or other such details.

Table 8-1. Details of participants in Trial 3.

Child	**Gender**	**Age at 01 /02/07 (years;months)**	**C.A.R.S**	**Thumbnail**
XCX	Boy	9;8	42	XCX is a withdrawn child who likes computers. He does not like stories, and does not tell them. He does not seem to understand the motives or emotions of character in stories. He will give an ear-piercing scream if asked to do something he does not want to do.
XHX	Boy	9;7	35	XHX likes computers. He likes strange and spooky stories and will retell simple stories he has seen on TV programmes or computer games. He sometimes seems to understand emotions and motives of characters.
XNX	Boy	8;7	38	XNX likes computers and space or fantasy stories. He does not understand the emotions or motives of the characters. He will retell stories he has already heard.
XJX	Boy	7;6	48	XJX is fascinated by words. He like computers and repetitive stories. May understand basic emotions such as happy and sad. He does not tell stories. He 'blocks out' adults by singing or reciting. He needs to constantly be re-focussed on any set task.
XDX	Boy	6;11	51	XDX does ***not*** like computers. He does like repetitive, interactive stories. He is unable to understand emotions or motives, and is unable to tell stories as he has little productive language. He may be anxious about doors.
XEX	Girl	6;6	35	XEX likes computers and stories. May understand basic emotions such as sad and happy. Will retell known stories, which she recites, and for which she has a very good memory.

8.4 Artefacts

Two main artefacts were used in this trial; the TouchStory program, and the narrative comprehension task. New versions of the narrative comprehension task were prepared using three shorter picture narratives than were used in trial 2.

8.4.1 TouchStory

TouchStory version 3 was used in this trial, recall that this produces two logs; one which records on screen activity and the other which creates a profile of each participant which forms the basis for adaptation. The presentation of t-stories in each session was organised to give smooth transitions in visual complexity. This gives a comfortable, predictable feel to the interface, which minimises visual dissonance and builds on participants' previous experience. Table 8-2 illustrates the visual complexity of images used in TouchStory, and shown the order in which t-stories are presented within a session. Illustrations of the t-stories used in the study can be found in Appendix G.

Table 8-2. Presentation order of t-stories within a session

Order of presentation	**Proto-narrative category**	**Visual complexity**	**Example image**
1	Character	Simple iconic images	
2	Background		
3	Reversible sequence		
4	Character	Graphical drawings, paintings, photos of simplified objects	
5	Background		
6	Reversible sequence		
7	Temporal sequence		
8	Narrative sequence		
9	Character	Photo-realistic images	
10	Background		
11	Reversible sequence		
12	Temporal sequence		
13	Narrative sequence		

8.4.2 Narrative Comprehension Tasks

Narrative comprehension tasks using three new stories were prepared for this trial. Laminated cards were prepared from three well regarded books in use at the school. These were The Big Box (Hunt & Brychta 1991b), The Ice Cream (Hunt & Brychta 2008), and Handa's Surprise (Browne 1994). Recall that one of the strengths of the Paris and Paris task is that it has been shown to be effective over a number of picture stories. The adapted questions and the scoring rubrics can be found, together with guiding examples from Paris & Paris, in Appendix D.

8.5 Procedures and measures

This section describes the structure of the study as a whole, and provides a timeline for the study. This is followed by a description of the more detailed structure of the rollout of t-stories. Finally the measures used in the study are described.

8.5.1 Trial timeline

The trial was a serial study in which the school was visited twice weekly in term time, on 21 occasions. The study was in two main parts, the pre-adaptive phase in which participant profiles were constructed but there was no adaptation to individual participants, and the adaptive phase in which the relative proportions of proto-narrative categories shown to the participant was adapted to his or her learning zone. The third and final phase (the post-adaptive phase) was a reprise of the early visits for comparison purposes.

An overview of the trial timeline is given in Table 8-3. During the pre-adaptive and adaptive phases the trial was structured into weeks, with two visits per week. To enhance predictability, new t-stories were introduced on every second visit (i.e. once per week). In the pre-adaptive phase intermediate visits were an exact repetition of the previous visit. In the adaptive phase, adaptation was applied in the intermediate visits. Where the adaptation indicated that the number of t-stories from a particular proto-narrative class should be increased, the extra t-stories were drawn from the pool of those already seen. The post-adaptive phase consisted of one visit (visit 19) in which the initial t-stories were re-presented, and one (visit 20) in which new, but similar, t-stories were presented. The school calendar did not allow the post adaptive visits to fall within one week. Also, in order to see all the participants despite illness and other demands on their time, the conceptual visits 19 and 20 both took place over more than one actual visit. There was no adaptation to the individual participant in the post adaptive phase.

The steady introduction of new t-stories on a weekly basis means that it is possible to measure participants' ongoing success with unseen t-stories, giving some measure of learning rather than remembering.

Table 8-3. Timeline for Trial 3.

Phase	Week/Visit	Introduction of new t-stories	Adaptive behaviour	Other
PRE-ADAPTIVE	1/1	Introductory set of t-stories used	-	NCT1
	1/2	-- no change --	-	
	2/3	One third t-stories replaced by new ones	-	
	2/4	-- no change --	-	
	3/5	One third t-stories replaced by new ones	-	
	3/6	-- no change --	-	Distractions put in place
	4/7	One third t-stories replaced by new ones	-	
ADAPTIVE	4/8	--no new t-stories introduced --	Adaptation applied	NCT2
	5/9	One third t-stories replaced by new ones	no additional adaptation	
	5/10	--no new t-stories introduced --	Adaptation applied	
	EASTER			
	6/11	One third t-stories replaced by new ones	no additional adaptation	
	6/12	--no new t-stories introduced --	Adaptation applied	
	7/13	Two t-stories replaced by new ones (only 2 due to technical difficulties)	no additional adaptation	
	7/14	--no new t-stories introduced --	Adaptation applied	
	8/15	One third t-stories replaced by new ones	no additional adaptation	
	8/16	--no new t-stories introduced --	Adaptation applied	
	9/17	One third t-stories replaced by new ones	no additional adaptation	
	9/18	--no new t-stories introduced --	Adaptation applied	NCT3
POST-ADAPTIVE	10/19	Reprise of visit 2 t-stories	--no adaptation--	
	HALF TERM			
	11/20	All new t-stories, but similar to visit 2	--no adaptation--	

The narrative comprehension task was used at three points in the trial; at the beginning of the trial, at the beginning of the adaptive phase, and at the end of the adaptive phase.

Distractions were introduced to this trial during visit 6 to tap into each participant’s level of engagement (measure M6 in Table 8-5). During trial 2 (Davis et al. 2007a) participants had shown no decrease in apparent engagement over twelve visits, indeed some participants appeared to become more engaged, for example becoming more focussed on getting the *right* answer. However there was no active attempt to distract the participants from TouchStory during trial 2. The distractions used in visit 6 were, first, a small attractive colourful toy and a colourful attractive book which were left near the touch screen prior to the participant's session with TouchStory. Second, attempts were made to distract the child while the TouchStory game was in progress, by asking, 'Why did you choose that one?' Boredom *per se* was not expected to be an issue as the participants were children with autism. The expectation was that, unless distractions were in the child's area of special interest, the expected routine activity, in this case TouchStory, would be preferred.

8.5.2 T-story rollout

Every alternate visit approximately one third of the t-stories were replaced by ones participants had not yet seen. This is illustrated in Table 8-4 which shows the pattern of rollout, and the t-stories used, in the pre-adaptive phase. This pattern of t-story introduction continued in the adaptive phase. A full list of t-story rollout throughout the study and visual images of all the t-stories used in the study (except those derived from published sources) can be found in Appendix G.

Table 8-4 Rollout of t-stories in pre-adaptive phase

The column t-story shows the name of the t-story, column stype indicates the proto-narrative category of the t-story (b:background; c:character; ns:narrative sequence; rs:reversible sequence; and ts: temporal sequence). The visit columns show whether the t-story was used on that visit; a '1' in the column indicates that it was.

t-story	stype	visit 1	visit 2	visit 3	visit 4	visit 5	visit 6	visit 7
b2	b	1	1					
c2	c	1	1					
Hairy	ns	1	1					
balloons	ts	1	1					
b3	b	1	1	1	1			
s3	c	1	1	1	1			
egg1a	rs	1	1	1	1			
bluevase	rs	1	1	1	1			
o3	rs	1	1	1	1			
Tick	ts	1	1	1	1			
Sit	ns	1	1	1	1	1	1	
egg2a	rs	1	1	1	1	1	1	
eggcooking	ts	1	1	1	1	1	1	
Bus	rs	1	1	1	1	1	1	
Sheep	b			1	1	1	1	
purplestar	c			1	1	1	1	
StarB	b			1	1	1	1	1
Orange	c			1	1	1	1	1
Beach	ns			1	1	1	1	1
newballoon	ts			1	1	1	1	1
c1	c					1	1	1
cross3	b					1	1	1
cross1	c					1	1	1
Hair_c	ns					1	1	1
o6a	rs					1	1	1
kiwi2	ts					1	1	1
b5	b							1
s1	c							1
Rain	ns							1
cross2	rs							1
egg3a	ts							1

Key to shading	This shading indicates a t-story which is being used for first time	This shading indicates a t-story which has been presented previously and is being used again.

8.5.3 Measures used

In this trial, as in the previous ones, the method of enquiry was by observation. Four recording methods were used:

Video recording. One camera was used which gave a side view of the participant, capturing the participant's general stance, attitude and interaction with the screen. Some facial expression was captured, but not eye gaze.

A log of answers given. This log was written to a database and was used in the adaptation process. It recorded, for each t-story instance completed by the participant, the first choice of answer docked, and whether it was correct.

Logs of participants' interactions with the screen. One such log was written for each participant session. These were text files and were more detailed than the database log. They recorded, for each t-story instance completed by the participant, each answer choice touched or moved across the screen, the positions the choice was moved through, whether the choice is correct, and whether the participant docked the choice (rather than just touching it or moving it on the screen without docking it).

Session notes. These were notes made during the sessions to keep a register of absences of participants and a note of remarkable events regarding problems encountered, and the attitude and wellbeing of participants.

The database log was used to provide measures of participants' success with TouchStory in terms of 'getting the right answer' (see measures M1 – M4 in Table 8-5).

Video sequences and text logs were used to provide two measures of participants' engagement with and enjoyment of the interaction with TouchStory (see measures M6 and M7 in Table 8-5).

Video sequences were used to score the narrative comprehension task, which provides a measure of real world narrative ability (see measure M8 in Table 8-5).

Last, session notes (see measure M5 in Table 8-5.) were used to provide a context for all these measures.

Table 8-5. Measures used in Trial 3.

Measure ID /source	**Measures used per participant**	**Reason**
M1/ Database log	For each proto-narrative category, during the pre-adaptive and adaptive phases; the *proportion* of t-story instances in which the correct answer was given at first attempt.	To see whether performance improves over the study, in particular in those proto-narrative categories targeted by the adaptation for this participant.
M2 / Database log	For each proto-narrative category, during the pre-adaptive and post-adaptive phases; the *proportion* of t-story instances in which the correct answer was given at first attempt.	To indicate whether any improvement shown by M1 comes from remembering the answers to specific t-stories, or whether more general learning had occurred.
M3 / Database log	For each proto-narrative category, during the adaptive phase; the numbers of correct and incorrect answers given to t-story instances at first attempt.	Measures M1 and M2 necessarily use proportions (it is a feature of the adaptation that the numbers of t-stories offered in each proto-narrative category are not kept constant. Presenting the actual numbers gives a context for interpreting measures M1 and M2.
M4/ Database log	For the proto-narrative categories which were the focus of adaptation for this participant, the proportion of *previously unseen* t-story instances in which the correct answer was given at first attempt.	To indicate whether any improvements shown by measure M1 and M2 above come from remembering the answers to specific t-stories, or whether more general learning had occurred. By considering only success with previously unseen t-stories, specific learned answers are eliminated.
M5/Session notes	For each visit a subjective measure of the mood and engagement of the participant during the session.	To place other results in context, for example to note whether a participant was upset in a particular session.
M6/ Video sequences and session notes	An examination of participants' reaction to the distraction put in place in visit 6.	To indicate whether the participant was actively engaged and interested in TouchStory.
M7/Text logs	An examination of the participant's interaction with the screen in the case that the first answer given was wrong.	To indicate whether the participant was actively engaged and interested in the right answer, and whether improvement followed.
M8 NCT/ Video sequences	Scoring for the 3 narrative comprehension tasks, according to the previously defined answer schemes.	To relate the above results to real world narrative ability.

At the beginning of the study a carer was present during sessions in addition to the experimenter if it was appropriate to the particular child for the particular activity. As the study progressed each child became confident and able to attend without a carer.

8.5.4 Simulated scenarios

In addition to the procedures and measures used with participants, two simulations of extreme conditions were carried out to further exercise the revised adaptive formula. These were carried out by the experimenter in the role of participant. The first role adopted being a participant who always gave the correct answer, and the second role being a participant who always chose the rightmost option.

8.6 Results and analysis

It was found that in each session, a participant skilled in manipulating the touch screen and confident of his or her answers could complete a set of t-stories in 2 minutes or less. A participant spending more time thinking or manipulating the images on the screen might take as much as 10 minutes.

Many of the results discussed in this chapter are based on the software log written by TouchStory to the database. The approach to data analysis and presentation was to carry out as much processing as possible within the database before exporting to Microsoft Excel for data visualization. The main SQL queries used in data derivation can be found in Appendix E.

The presentation of results begins by considering the impact of the adaptation on the proto-narrative instances presented to, and seen by, individual participants. This is shown in section 8.6.1, followed by the impact of adaptation in the two simulated scenarios in section 8.6.2. The success of individual participants with TouchStory is presented in section 8.6.3. Participants' engagement with, and use of, TouchStory is considered in section 8.6.4. Last, the work is set in the context of real world narratives by considering the narrative comprehension tasks (measure M8) in section 8.6.5.

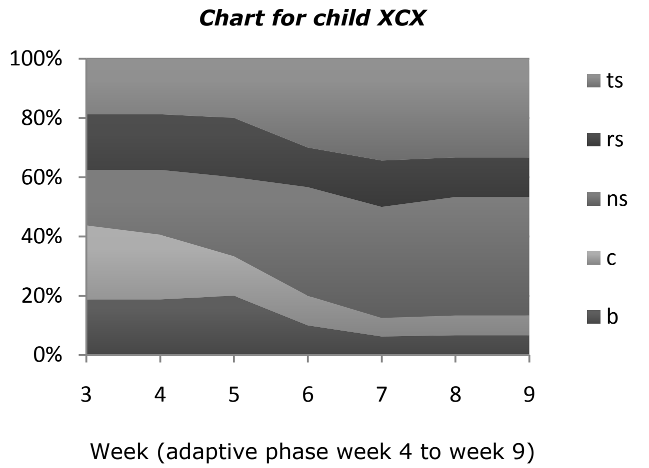
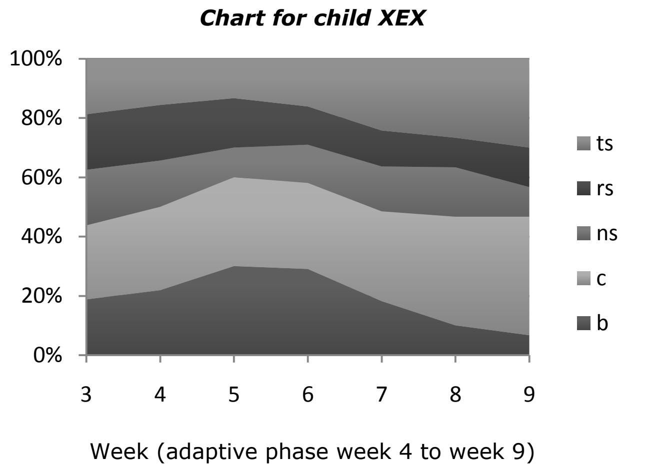
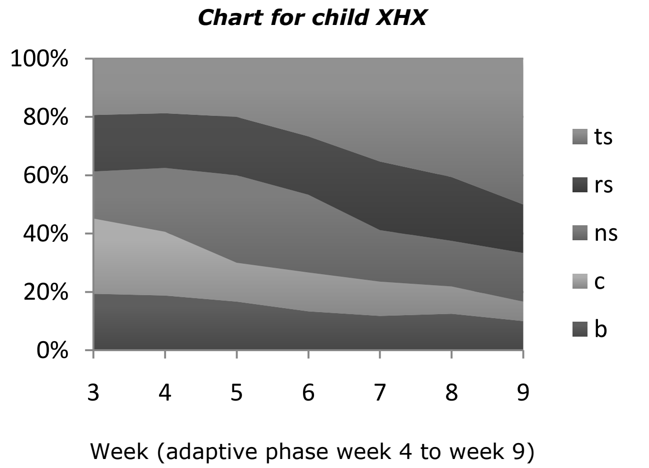
8.6.1 The impact of adaptation on the proto-narrative instances seen by individual participants

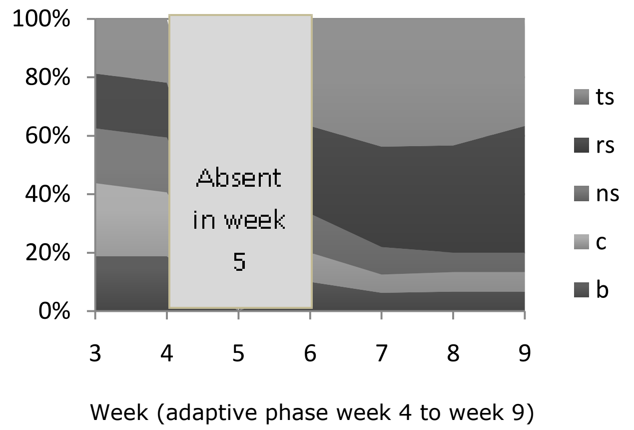
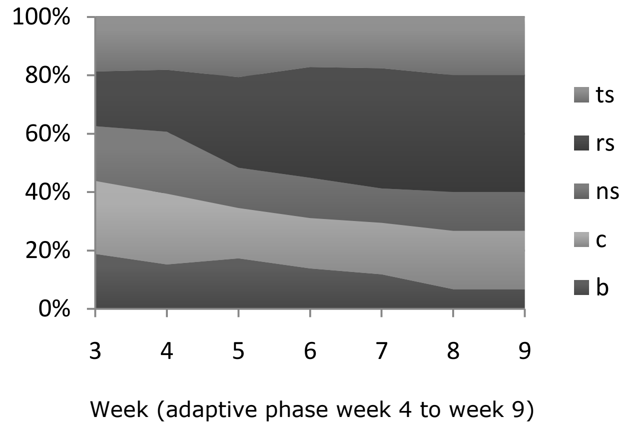
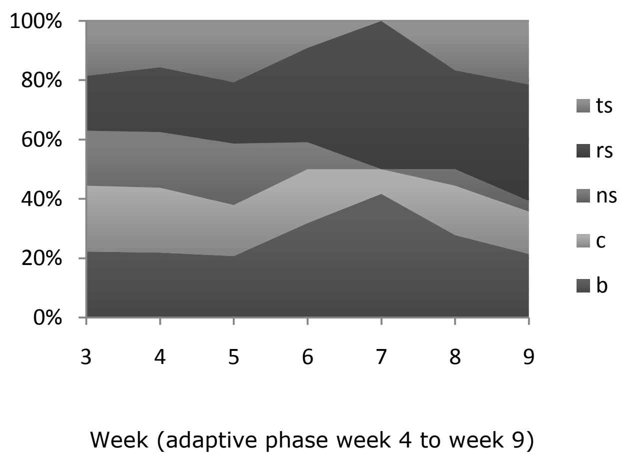
The impact of the adaptation on the proto-narrative instances presented to, and seen by, individual participants is shown in Table 8-6. The table shows considerable variety among the participants as follows. It can be seen from Table 8-6 that:

- The focus for participant XCX was on narrative (ns) and temporal (ts) proto-narrative categories.
- The focus for participant XEX was on background (b), character (c), and temporal (ts) proto-narrative categories.
- The focus for participant XHX was on temporal (ts) proto-narratives with a small early focus on narrative (ns) proto-narratives.
- The focus for participant XNX was on reversible (rs) and temporal(ts) proto-narrative categories.
- The focus for participant XJX was on reversible (rs) proto-narratives.
- The focus for participant XDX was on background (b) and reversible (rs) proto-narrative categories.

In some cases (consider participants XEX and XNX in Table 8-6) the focus of the adaptation is seen to change as the trial progresses. This can occur for three reasons: the child may become sufficiently competent in the category that it is no longer a focus of positive adaptation; the participant may improve in a category such that it becomes good enough to be the focus of positive adaptation; last, stochastic effects in producing the desired number of t-stories for a session could switch focus between two categories in which the participant was similarly competent.

Table 8-6.The impact of adaptation on the proto-narrative instances seen by individual participants.

Child	**Commentary**	**Proportion contributed each week to the overall session by each proto-narrative category**
XCX	Number of t-stories answered in the pre-adaptive phase = 108 with success b=89%, c=90%, ns=67%, rs =82%, ts 66 % --------------------------------- The effect of this adaptation was to steadily increase the proportions of narrative (ns) and temporal (ts) t-stories --------------------------------- Number of t-stories answered in the adaptive phase =153 of which b=17, c=15, ns=53, rs=24, ts=44	
XEX	Number of t-stories answered in the pre-adaptive phase = 108 with success b=53%, c=68%, ns= 59%, rs=34%, ts=14% --------------------------------- Early in the adaptive phase the effect of the adaptation was to increase the proportion of background t-stories (b). As the participant's profile changed the focus moved to character t-stories (c), and towards the end of the adaptive phase focus was also on temporal t-stories (ts) --------------------------------- Number of t-stories answered in the adaptive phase = 150 of which b=33, c=36, ns=22, rs=23, ts=36	
XHX	Number of t-stories answered in the pre-adaptive phase = 107 with success b=100%, c=95%, ns=75%, rs=100%, ts=86% --------------------------------- There was a steady increase the proportion of temporal t-stories (ts) --------------------------------- Number of t-stories answered in the adaptive phase = 172 of which b=23, c=20, ns=37, rs=35, ts=57	

Child	Commentary	Proportion contributed each week to the overall session by each proto-narrative category
XNX	Number of t-stories answered in the pre-adaptive phase = 108 with success b=100%, c=95%, ns=88%, rs=83%, ts=62 --------------------------------- The adaptation produced a steady increase in the proportions of reversible (rs) and temporal (ts) t-stories, towards the end of the adaptive phase the proportion of temporal t-stories declines while the proportion of reversible t-stories continues to increase. --------------------------------- Number of t-stories answered in the adaptive phase = 138 of which b=12, c=12, ns=14, rs=47, ts=53	***Chart for child XNX*** 
XJX	Number of t-stories answered in the pre-adaptive phase = 80, with success: b=93%, c=39%, ns=38%, rs=42%, ts=43% --------------------------------- The adaptation produced a steady increase in the proportion of reversible (rs) t-stories. --------------------------------- Number of t-stories answered in the adaptive phase = 139 of which b=17, c=26, ns=20, rs=50, ts=26	***Chart for child XJX*** 
XDX	Number of t-stories answered in the pre-adaptive phase = 59, with success: b=50%, c=29%, ns=20%, rs=42%, ts=9% --------------------------------- The adaptation produced an increase in the proportions of background (b) and reversible (rs) t-stories. The spikes in week 7 are caused by the participant shutting down the game prematurely and hence seeing a reduced set of t-stories. --------------------------------- Total t-stories answered in the adaptive phase=125 of which: b=33, c=20, ns=13, rs=40, ts= 19	***Chart for child XDX*** 

8.6.2 The impact of adaptation during simulated scenarios

Recall that two simulated scenarios were carried out. In the first scenario the 'participant' gave the correct answer to every t-story, in the second the 'participant' always chose the right-most option. In the first scenario (and of course in this case the participant has no learning needs to adapt to) the outcome was very different on different runs. Results from two such runs are shown in Table 8-7 and Table 8-8. In the run shown in Table 8-7 there were 12 adaptive rounds, twice as many as were possible in trial 3. However, it can be seen from these results that the outcome, even after many rounds of adaptation, scarcely escapes from the stochastic effects which occur in the first adaptive iteration. For example, in the first run the reversible proto-narrative category (rs) was positively targeted in the first adaptive round, and this positive targeting continued through every one of the 12 rounds. Similarly, in the second run the background (b) and narrative (ns) proto-narrative categories were positively targeted in the first adaptive round, and again this positive emphasis continues through every adaptive round.

Table 8-7 The effects of adaptation in a simulated scenario in which the participant always gave the correct answer (first run). The column 'adaptation round' shows the number of times adaptation has been applied and the remaining columns show the outcome of the adaptive formula in terms of the number of t-stories to be shown from each proto-narrative category.

adaptation round	proto-narrative category b	proto-narrative category c	proto-narrative category ns	proto-narrative category rs	proto-narrative category ts
1	3	2	3	5	2
2	2	1	2	8	2
3	2	1	1	10	1
4	1	1	3	9	1
5	1	1	2	10	1
6	1	2	1	9	2
7	1	2	1	10	1
8	1	1	1	11	1
9	2	1	1	10	1
10	3	1	1	9	1
11	2	2	1	9	1
12	1	1	1	11	1

Table 8-8 The effects of adaptation in the simulated scenario in which the participant always gave the correct answer (second run). The column 'adaptation round' shows the number of times adaptation has been applied and the remaining columns show the outcome of the adaptive formula in terms of the number of t-stories to be shown from each proto-narrative category

adaptation round	**proto-narrative category b**	**proto-narrative category c**	**proto-narrative category ns**	**proto-narrative category rs**	**proto-narrative category ts**
1	4	3	4	2	2
2	5	3	5	1	1
3	5	2	6	1	1
4	6	1	6	1	1
5	6	1	5	2	1
6	6	1	6	1	1

In the second case where the participant always chose the rightmost option, the effect of the adaptive function was to keep offering 3 t-stories from each proto-narrative category, which may be considered an appropriate response. Over time a real life participant might begin to answer differently either because he or she begins to understand one of the proto-narrative categories, or decides to choose to play as intended. In either case the adaptation is able to respond.

8.6.3 The development of the TouchStory profile of each participant over time.

In order to provide context, an overview of each participant's TouchStory profile over the study as a whole is provided in Table 8-9. The column *t-stories answered* shows the number of distinct t-stories seen by the participant, regardless of the number of occasions on which it was seen (that is, the cardinality of the set of t-stories seen by the participant). The column *t-story instances answered* is a count of every t-story instance answered, including duplicates, that is, the t-story is counted regardless of whether it has been seen by the participant in a previous session. The column *instances answered correctly* shows how many of these *t-story instances* were answered correctly by the participant at first attempt. The column *% of instances answered correctly* shows the percentage of *t-story instances* that were answered correctly by the participant at first attempt. The final column *t-stories answered wrongly at least once* shows the number of distinct t-stories answered wrongly on at least one occasion by the participant, regardless of the number of occasions on which it was seen. The table is presented in decreasing order of the column *% of instances answered correctly.*

Table 8-9. An overview of participants' interaction with TouchStory during trial 3.

Participant	t-stories answered	t-story instances answered	Instances answered correctly	% of instances answered correctly	t-stories answered wrongly at least once
XHX	67	311	284	91%	16
XCX	67	289	249	86%	24
XNX	67	263	175	67%	31
XEX	67	306	175	57%	48
XJX	68	247	82	33%	46
XDX	68	210	67	32%	50

Recall that in answering a t-story instance a participant chooses one of three pictures; inspection of the column *% of instances answered correctly* in Table 8-9 suggests that, over the study as a whole, participants XJX and XDX guess their answers. Participants XHX and XCX, on the other hand, score very highly over the study taken as a whole, and participants XNX and XEX score in the mid range.

Of greater interest is whether the individual participants *improved* during the study; that is whether TouchStory afforded the individual participant the opportunity to guess; to exercise a skill they already possessed; or to learn. Of the six participants three show improved performance with TouchStory over the trial. These are participants XCX, XEX and XHX. Results for these participants are presented next: all the results pertinent to measures M1 – M5, which are concerned with participants' success with the TouchStory task, are presented in Appendix E. Some figures from Appendix E are reproduced in this section to aid comparison and avoid page turning.

TOUCHSTORY PROFILE FOR PARTICIPANT XCX

Participant XCX was a boy aged 9 years 8 months at the beginning of the trial with a CARS autism score of 42 (for further details see Table 8-1). He was quite competent with t-stories from the beginning, scoring more than 50% in every proto-narrative category in the pre-adaptive phase. The effect of the adaptive formula was to focus on those categories in which he was weakest in the pre-adaptive phase, that is on narrative (ns) and temporal (ts) proto-narrative categories. His performance improved in general in the adaptive phase, but the greatest improvement was seen in the narrative and temporal categories targeted by the adaptive formula, shown in Figure 8-1.

Chart title: Pre-adaptive vs. adaptive phases for participant XCX

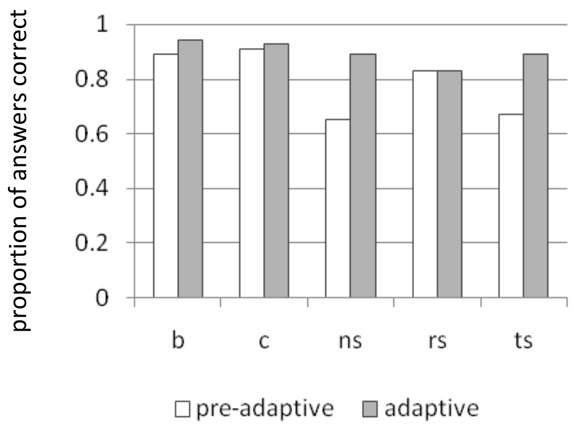


Figure 8-1.For each proto-narrative category the proportion of correct answers during the pre-adaptive and adaptive phases for participant XCX. This shows greater improvement in the proto-narrative categories ns and ts, which were the focus of adaptation.

All the results indicate that participant XCX has become more successful with the target proto-narrative categories ts and ns during the trial. The results strongly suggest a genuine improvement in competence with t-stories for the following reasons: he saw a robust number of t-story instances during the adaptive phase (measure M3); the improved success continued into the post-adaptive phase (measure M2); improved success can also be seen in the target categories when specific learned answers are eliminated by limiting consideration to previously unseen t-stories (measure M4). Measures M3, M2 and M4 for this participant are illustrated by Figure 8-2, Figure 8-3 and Figure 8-4 respectively.

Chart title: Numbers of correct and incorrect answers given by participant XCX

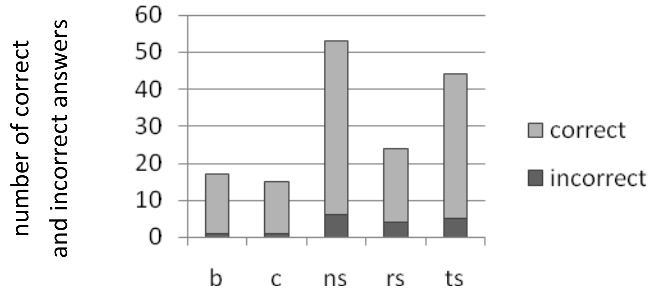


Figure 8-2 The number of correct and incorrect answers given by participant XCX during the adaptive phase.

Chart title: Pre-adaptive vs. post-adaptive phases for participant XCX

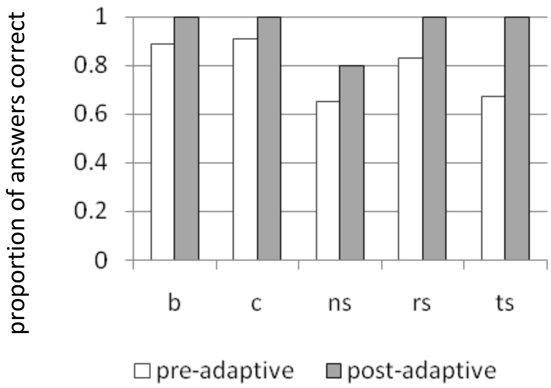


Figure 8-3 Proportion of correct answers in each proto-narrative category during the pre-adaptive and post-adaptive phases for participant XCX

Chart title: Proportion of correct answers to new t-stories for participant XCX

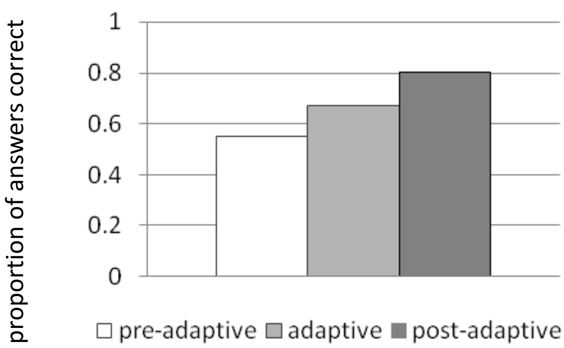


Figure 8-4 The proportion of correct answers to new t-stories in the proto narrative categories ns and ts, which were the focus of the adaptation for participant XCX

TOUCHSTORY PROFILE FOR PARTICIPANT XEX

Participant XEX was a girl aged 6 years 6 months at the beginning of the trial with a CARS autism score of 35 (for further details see Table 8-1). The profile of participant XEX is similar to that of participant XCX in that improvement is seen throughout the trial, in particular in those proto-narrative categories that were the focus of adaptation (b, c and ts). Further, measures M3 and M4 (described in Table 8-5) indicate a genuine improvement in competence with new unseen t-stories. Measures M1, M2, M3 and M4 are illustrated for this participant by figures: Figure 8-5, Figure 8-6, Figure 8-7 and Figure 8-8. However, in general she does not score so highly as XCX. The initial effect of the adaptive formula in her case was a positive focus on those categories in which she did *best* in the pre-adaptive phase, namely background and character. Very quickly her success with background proto-narratives improves to the point that it is no longer a focus for positive adaptation. Her success with temporal narratives, previously her least successful, improves to a point where it also becomes a focus for positive adaptation.

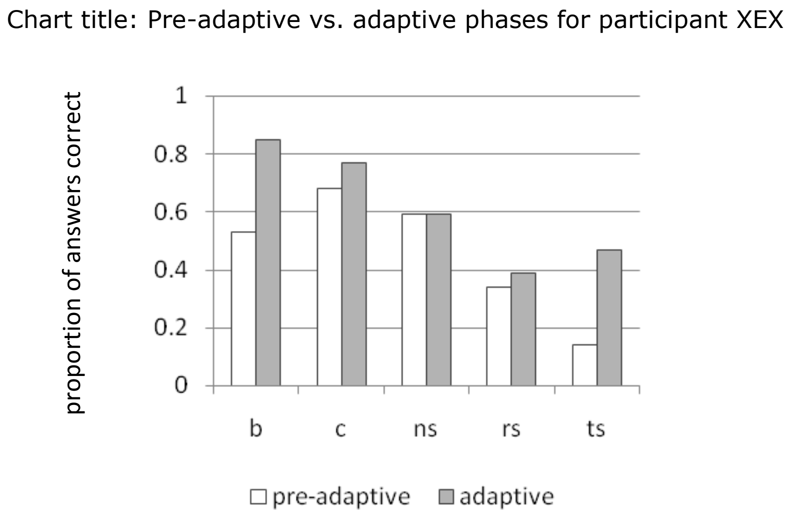


Figure 8-5 For each proto-narrative category the proportion of correct answers during the pre-adaptive and adaptive phases for participant XEX. This shows greater improvement in the proto-narrative categories b, c and ts, which were the focus of adaptation

Chart title: Pre-adaptive vs. post-adaptive phases for participant XEX

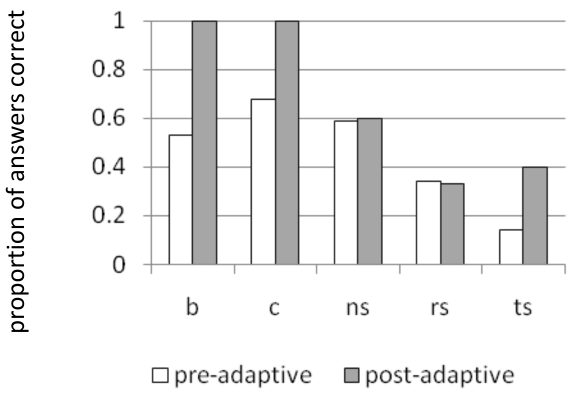


Figure 8-6 Proportion of correct answers in each proto-narrative category during the pre-adaptive and post-adaptive phases for participant XEX

Chart title: The number of correct and incorrect answers given by participant XEX

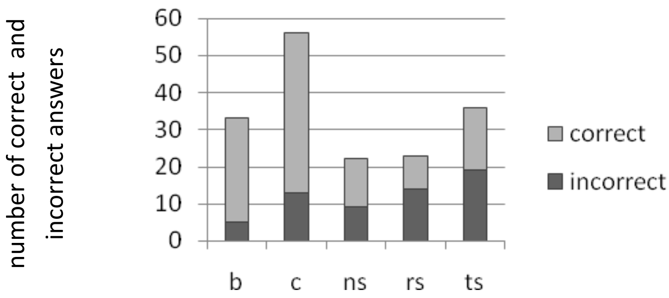


Figure 8-7 The number of correct and incorrect answers given by participant XEX during the adaptive phase.

Chart title: Proportion of correct answers to new t-stories for participant XEX

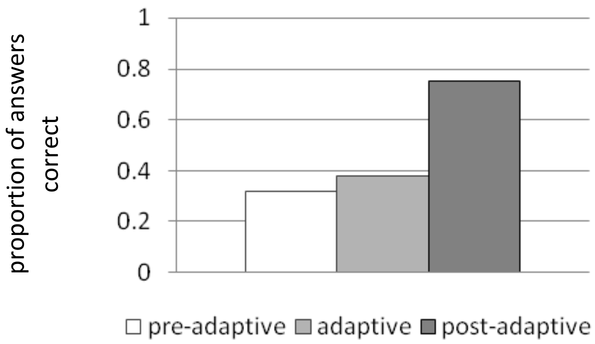


Figure 8-8 The proportion of correct answers to new t-stories in the proto-narrative categories b,c and ts, which were the focus of the adaptation for participant XEX

TOUCHSTORY PROFILE FOR PARTICIPANT XHX

Participant XHX was a boy aged 9 years 7 months at the beginning of the trial with a CARS autism score of 35 (for further details see Table 8-1). He was very competent from the beginning but was nevertheless highly engaged, apart from being somewhat distracted in visit 10. He did comment that he found the task easy. In his case, the adaptation focussed on temporal proto-narratives, with a small early focus on narrative proto-narratives; in the adaptive phase he improved in these categories as can be seen in Figure 8-9. The same figure shows that he did less well in the adaptive phase for the background and reversible sequence proto-narrative categories; however inspection of Figure 8-10 shows that the number of wrong answers was very small and may be attributed to carelessness or confusion over a particular t-story. Similarly, he did less well in the narrative and reversible categories in the post-adaptive phase, again the numbers are small, this chart is not reproduced here but can be found in Appendix E.

Success with unseen t-stories in the temporal proto-narrative category, which was the main focus of adaptation for this participant, declines slightly in the adaptive phase, but increases to 100% in the post-adaptive phase, see Figure 8-11.

Chart title: Pre-adaptive vs adaptive phases for participant XHX

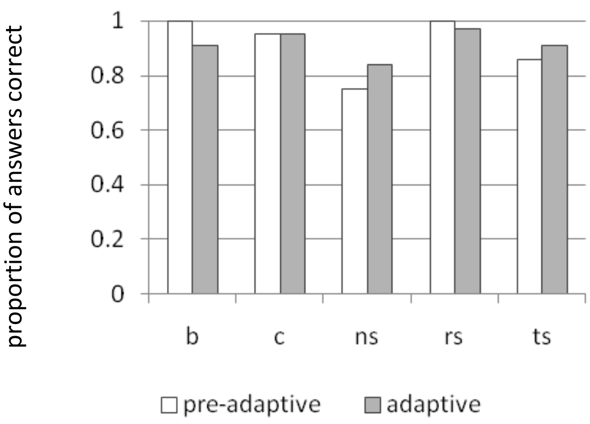


Figure 8-9 For each proto-narrative category the proportion of correct answers during the pre-adaptive and adaptive phases for participant XHX. This shows greater improvement in the proto-narrative category ts, which was the main focus of adaptation

Chart title: Number of correct and incorrect answers given by participant XHX

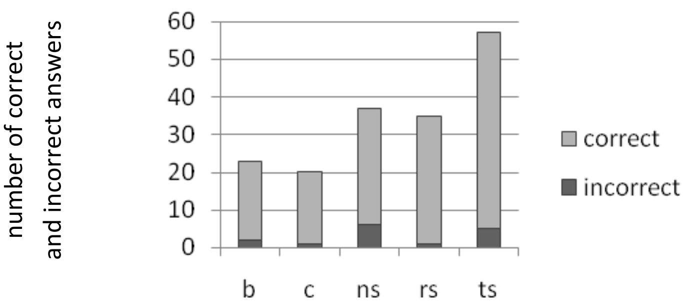


Figure 8-10 The number of correct and incorrect answers given by participant XHX during the adaptive phase.

Chart title: Proportion of correct answers to new t stories for participant XHX

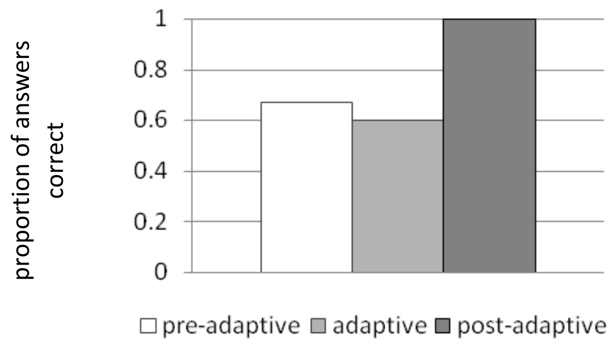


Figure 8-11 The proportion of correct answers to new t-stories in the temporal proto-narrative category which was the main focus of the adaptation for participant XHX

TouchStory Profile for Participant XNX

Participant XNX was a boy aged 8 years and 7 months at the beginning of the trial with a CARS autism score of 38. He demonstrated understanding and ability with TouchStory in the pre-adaptive phase, being most successful with proto-narratives from the background category in which he scored 100%, and least successful with proto-narratives from the temporal category in which he scored just over 60%, illustrated in Figure 8-12. However, he did far less well in all proto-narrative categories during the adaptive phase (visits 8 to 18). In particular his success in the narrative and temporal proto-narrative categories was scarcely better than guessing, as can be seen by referring again to Figure 8-12. He was distracted during TouchStory sessions at this time, see Figure 8-13, although he was compliant, ‘going through the motions’ of playing the TouchStory game; the number of t-stories attempted in the adaptive phase can be seen in Figure 8-14. This down-turn in interest is attributed to external factors; the family previously lived in another country which they revisited during the Easter vacation. After Easter (from visit 11 in the trial), his teacher reports, he was unsettled in *all* his school work. This is not surprising; recall that children with autism are particularly likely to find change difficult. As an aside; this participant was reported to be speaking positively of TouchStory nearly a year later, in May 2008.

In the post-adaptive phase he continued to do less well overall than in the pre-adaptive phase in most proto-narrative categories (i.e. background, reversible, and temporal), see Figure

8-15. When consideration is limited to previously unseen t-stories from the proto-narrative categories targeted by the adaptation, success in the post-adaptive phase returns to pre-adaptive levels, see Figure 8-16.

Chart title: pre-adaptive vs adaptive phases for participant XNX.

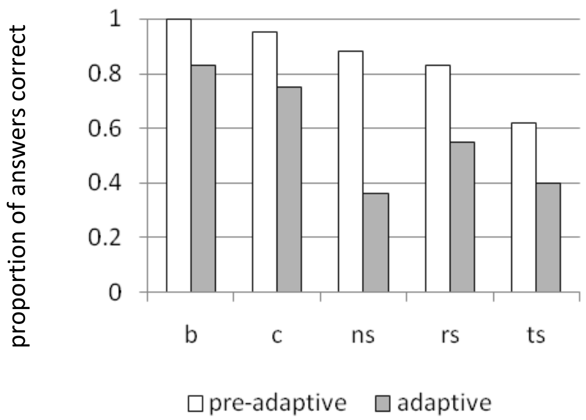


Figure 8-12 For each proto-narrative category the proportion of correct answers during the pre-adaptive and adaptive phases for participant XNX.

Chart title: Mood and engagement

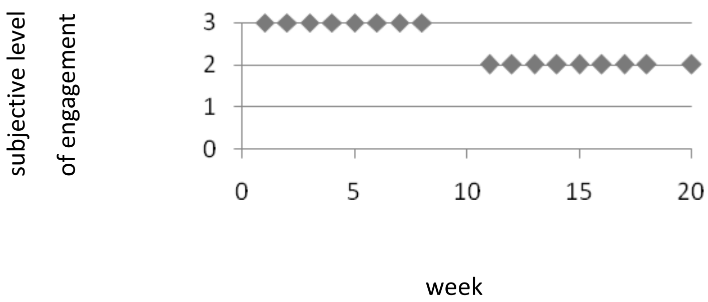


Figure 8-13 A subjective measure of mood and engagement with TouchStory during trial 3 where 3=highly engaged, 2=not fully engaged, going through the motions, 'not themselves', 1= distracted or needing to be coaxed, 0= present but interaction refused, missing values= the participant was not available (e.g. ill, at special classes off site, or on holiday)

Chart title: number of correct and incorrect answers given by participant XNX

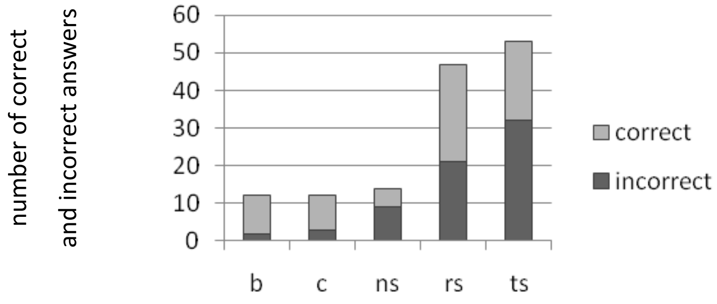


Figure 8-14. The number of correct and incorrect answers given by participant XNX during the adaptive phase.

Chart title: Pre-adaptive and post-adaptive phases for participant XNX.

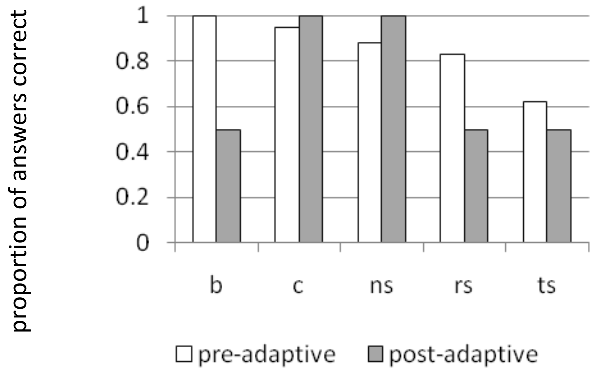


Figure 8-15. Proportion of correct answers in each proto-narrative category during the pre-adaptive and post-adaptive phases for participant XNX.

Chart title: Pre-adaptive vs post-adaptive phases for participant XNX.

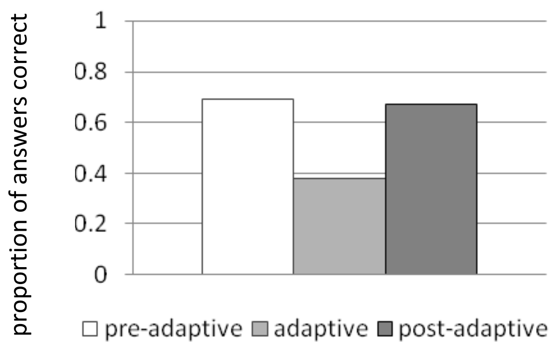


Figure 8-16. The proportion of correct answers to new t-stories in the proto narrative categories ns and ts, which were the focus of the adaptation for participant XNX.

TOUCHSTORY PROFILE FOR PARTICIPANT XJX

Participant XJX was a boy aged 7 years and 6 months at the beginning of the trial with a CARS score of 48 (for further details see Table 8-1). This participant did not improve during trial 3. The issue, once known, was straightforward. This participant was fascinated by words. The final TouchStory screen displays the words ‘Thank you’. His goal, it seemed, became to get to this final screen as quickly as possible, and his route to that became to always dock the middle t-story option as his answer. This behaviour, observed in the pre-adaptive phase, was reported in Davis et al. (2007b). While a number of strategies were considered, it was decided to continue with repeated exposures to TouchStory. However, in the event, his behaviour pattern continued. His initial interest in TouchStory (before he knew about the final screen), and his decline in engagement is shown in Figure 8-16. The full range of charts for this participant can be found in Appendix E, but are not reproduced here. His case is considered again under reflection and engagement in section 8.6.4

Chart title: A subjective measure of mood and engagement

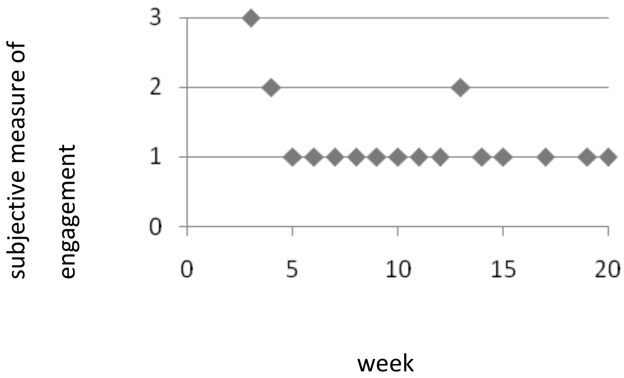


Figure 8-17. A subjective measure of mood and engagement for participant XJX throughout trial 3 where 3=highly engaged, 2=not fully engaged, going through the motions, 'not themselves', 1= distracted or needing to be coaxed, 0= present but interaction refused, missing values= the participant was not available (e.g. ill, at special classes off site, or on holiday).

TOUCHSTORY PROFILE FOR PARTICIPANT XDX

Participant XDX was a boy aged 6 years and 11 months at the beginning of the trial with a CARS autism score of 51. Unlike participant XJX, he does not like computers; he recognises a 'close' button and will use it to shut programs down.

Chart title: A subjective measure of engagement

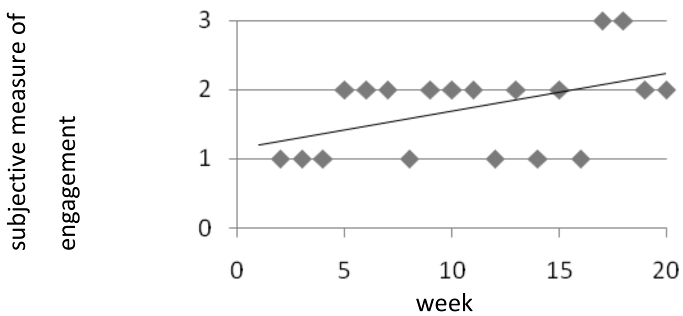


Figure 8-18 A subjective measure of mood and engagement for participant XDX throughout trial 3 where 3=highly engaged, 2=not fully engaged, going through the motions, 'not themselves', 1= distracted or needing to be coaxed, 0= present but interaction refused, missing values= the participant was not available (e.g. ill, at special classes off site, or on holiday)

The full set of graphs for this participant can be found in Appendix E. While his profile did not develop in terms of success during the study, he did become considerably more confident and at ease using TouchStory as the trial progressed. The levels of engagement observed subjectively during the sessions are shown in Figure 8-18. The trend line shows, overall, an increasing level of engagement.

8.6.4 Reflection and engagement

This section is concerned with participants' levels of engagement with TouchStory. Three measures of engagement were used, these being measures M5, M6 and M7 listed in Table 8-5. The results are in two parts. The first part is concerned with engagement of participants during the pre-adaptive phase including the distractions put in place in visit 6. The second part is concerned with the details of on-screen interaction during the whole trial.

Reflection and engagement during the pre-adaptive stage. The reflection and engagement of participants during the pre-adaptive phase of the study was presented in Davis et al. (2007b), the procedures and artefacts used are described in section 8.5. The results are summarised below.

The distractions put in place in visit 6 were mostly ignored by the participants. One participant noticed the toy, picked it up and played with it enthusiastically. He was easily refocused, with "would you like to play with TouchStory now?" He made an enthusiastic "Yeah" and abandoned the toy. Another participant noticed the book and picked it up, but quickly put it down to play with TouchStory. The attempts to interrupt participants by asking questions while the TouchStory game was in progress elicited no response at all from 5 of the 6 participants; they remained focussed on the game and did not answer. One participant did respond when asked "Why did you choose that one?" several times with, "because it was right".

Consideration of strategies used and behaviours displayed by participants while actively engaged in the interactions with TouchStory was focussed on two points. The first point being the moment when the participant has to choose which of the three images to dock. The second moment occurs if and when the participant docks an image which is wrong. The findings are presented in Table 8-10.

Table 8-10 Strategies adopted by participants at the moment of choosing which of the three images to dock and the moment if and when the participant docks an image which is wrong

Participant	**Initial image selection**	**Strategy when wrong**
XCX	He appears actively engaged in getting the 'right answer' at first docking. Having selected an image he occasionally reconsiders and makes another selection before docking.	In almost all cases he selects and docks another image. He usually moves the 'wrong' image away from the dock zone, prior to making his second selection.
XEX	This child also chooses answers from all three positions, but favours the middle position, choosing that for over half her answers.	This child's strategy when the initial selection was wrong was to select and dock another image. In visit 3 this happened on every occasion.
XHX	This child actively chooses from the available answers.	This child used a variety of strategies: consider visit 5; for 2 of the t-stories (types background and temporal sequence) he selected and docked a second option—these were both answered correctly on the subsequent visit, but for the third (type narrative sequence) he moved straight on to the next t-story without a second attempt, and this t-story was answered incorrectly again on the subsequent visit.
XNX	This child actively selects from the available images. Having selected an image he occasionally reconsiders and makes another selection before docking.	He moves the 'wrong' image away from the dock zone, prior to making his second selection.
XDX	When first seen he did not attempt to dock any t-story images, moving images in a seemingly random manner. By visit 7 he was docking an image for every t-story offered.	By visit 7, after docking a wrong image, this child leaves it in place, and moves the other two images to the upper half of the screen, covering other images in the t-story, thus creating the effect of the reward for a correct answer.
XJX	On visit 3 (the first on which he saw TouchStory) he selected the middle image first on 12 out of 16.occasions. He self corrected on 2 occasions. On subsequent visits he selected the middle image first in every instance.	On visit 3 he chose another image on 6 occasions, and moved straight on to the next t-story on 3 occasions. By visit 7 always moved straight on to the next t-story.

Reflection and engagement over the whole study. In considering reflection and engagement over the whole of trial 3, particular attention was paid to measure M7. Detailed analysis of the text logs was carried out, encoding the interaction details whenever a wrong answer was touched or moved. The encoding scheme was devised by the current author, as follows:

- An option which is touched, moved to the empty panel and docked is represented by its option number, e.g. 1
- An option which is touched and moved, but not docked is represented by the option number in brackets, e.g. (1)
- An option which is touched, but not moved, or moved only minimally is shown in double brackets, e.g. ((1))

This is illustrated by the following example which presents an example log followed by its encoded representation. Note that to aid readability and save space the trajectory points of options are shown as comma delimited lists; the actual TouchStory output uses new line as the delimiter.

1. Mon Mar 05 10:02:29 GMT 2007
2. story s3
3. time 10:2:29
4. ***option 0 (wrong) selected***, option 0 at 138 401, option 0 at 174 407, option 0 at 195 412, option 0 at 188 408, option 0 at 168 401, option 0 at 147 391, option 0 at 133 387, option 0 at 129 385, option 0 at 129 385
5. time 10:18:26
6. ***option 2 (wrong) selected***
7. time 10:18:26
8. ***option 1 (correct) selected***, option 1 at 401 391, option 1 at 356 316, option 1 at 315 226 option 1 at 247 145, option 1 at 237 136, option 1 fitting*********

The above log would be coded as shown in Table 8-11 in which t-story→s3 (from line2); visit→v3 (from line1); 1st choice → (0) ((2)) 1 (from lines 4 to 8). As this is a correct answer no further choices were made.

Table 8-11 Encoded log

t-story	**visit**	**1st choice**	**2nd choice**	**3rd choice**
s3(1)	v3	(0) ((2)) 1		

Examples showing how the encoding is to be read are given in Table 8-12.

Table 8-12. Examples of the interpretation of coded logs.

t-story	visit	1st choice	2nd choice	3rd choice	Interpretation
s3(1)	v3	(0)1			Choice 1: The participant moves but does not dock the answer in position zero i.e. the leftmost one, shown by (0), he then tries again and ***docks*** the answer from position 1 i.e. the middle one, which is the correct answer.
sheep(1)	v3	2	1		Choice1: The participant docks option 2, which is wrong, Choice 2: He then tries again and docks option 1 which is correct.
Sit(0)	v3	1			Choice1: The participant docks option 1 which is wrong. He does not try again.
sheep(1)	v4	((1))2	1		Choice 1: The participant touches but does not move option 1, shown by ((1)), but then docks option 2, which is wrong. Choice 2: He then tries again, returning to option 1 and docking option1, which is correct.
Sit(0)	v4	1	2	0	Choice 1: The participant docks option 1, which is wrong. Choice 2: He then tries again and docks option 2, which is also wrong. Choice 3: He tries again and docks option 0, which is correct.
Hair _c(0)	v5	2	1	(0)(1)(2)0	Choice 1: The participant docks option 2, which is wrong. Choice 2: He then tries again and docks option 1 which is wrong. Choice 3: He tries again, moving but not docking option 0, shown by (0); then moving but not docking option 1, shown by (1); then moving but not docking option 2, shown by (2); finally docking option 0, which was correct.

In this study, the encoding was done by hand using the search function of the Notepad editor to search for the word ‘wrong’ in the text logs. This was quite time consuming and for larger quantities of data it would be worthwhile to develop a program to do the encoding. The encoded logs can be found in Appendix E.

REFLECTION AND ENGAGEMENT FOR PARTICIPANT XCX

The results of the log files strongly support the proposal that this participant is self-monitoring at both selection points. With regard to the first selection point, on 21 occasions he touched or moved an answer option without docking it (possibly as part of the thinking process) before selecting the correct answer and docking that. With regard to the second selection point, on 40 occasions the first answer he docked was wrong. He tried alternative answers on 39 of these 40 occasions, his second choice of answer was correct on 23 of those occasions, and his third choice was correct on the remaining 16 occasions.

REFLECTION AND ENGAGEMENT FOR PARTICIPANT XHX

Again the results strongly support the view that this participant is self-monitoring at both selection points. Considering the first selection point, on 10 occasions he touched or moved an answer option without docking it, before selecting and docking the correct answer. With regard to the second selection point there is one anomaly in the particular case of the t-story ‘Sit’. He give the same wrong answer to ‘Sit’ on 6 occasions, on 5 of which he did not make a second choice of answer, but moved straight to the next t-story. Although the author asked him about this, he gave no explanation or indication why. With the exception of this particular t-story, his usual strategy at the second selection point was to make one more selection and dock that, but if that was wrong he did not dock the third (and possibly now obviously correct) option. Overall he was wrong at first attempt on 27 occasions. He made no second choice on 11 of these occasions (including the 5 already mentioned for the t-story Sit), but moved straight on to the next t-story. For the remaining 16 t-stories he made a second choice of answer, and in one case only he also made a third choice of answer.

REFLECTION AND ENGAGEMENT FOR PARTICIPANT XEX

This participant showed a developing strategy during the early visits. During the first visit she showed self monitoring at the first selection point on two occasions. However her first choice of answer was wrong on 7 occasions in visit 1, and on 6 of these occasions she moved straight to the next t-story. On visit 2 she used all the attempts necessary to get the correct answer on every occasion. On visit 3 she touched or moved options at selection point 2 before finally selecting an option to dock on 4 out of 9 occasions. Over the whole study, except for visit 1, she generally made alternative choices when at selection point 2, and was usually correct on second attempt.

REFLECTION AND ENGAGEMENT FOR PARTICIPANT XNX

At the beginning of the study this participant showed evidence of reflection at both selection points. Recall that later in the study he became disengaged with all his school work. Subjectively he appeared to be 'going through the motions' of interacting with TouchStory during the later visits. This lack of attention can be seen in the logs of visits 13 and 15 in particular, where repetitive patterns of selection were seen. Even so there was some evidence of self monitoring.

o balloons (2)	v13	((1))2		
o bus(0)	v13	1	(2)0	
o cats(0)	v13	1	2	0
o dogs(0)	v13	1	2	0
o eggcooking(2)	v13	((1))0	1	2
o eggmeal(0)	v13	1	2	0
o flower(0)	v13	1	(2)0	
o juice(0)	v13	1	2	0
o kiwi1(2)	v13	1	2	
o kiwi2(0)	v13	1	2	0
o opeel(0)	v13	2	0	

He showed a similar pattern on visit 15 as shown in the list below:

o eggmeal(0)	v15	2	1	0
o flower	v15	2	1	0
o juice	v15	(2)0		
o kiwi2(0)	v15	2		
o NFB(1)	v15	2	1	
o o6	v15	2		
o opeel	v15	2	1	0

○ Ted(0)	v15	2	1	0
○ Tedstory	v15	2	1	

These strong patterns were not seen on other visits.

REFLECTION AND ENGAGEMENT FOR PARTICIPANT XJX

No evidence of reflection or self-monitoring was found for this participant after his first session, which was visit 3. After visit 3 he always chose the middle option at the first selection point, and he moved straight to the next t-story on all but 4 occasions at the second selection point for the remainder of the trial.

REFLECTION AND ENGAGEMENT FOR PARTICIPANT XDX

The coding was not attempted for this participant. An example log extract is shown for this participant in Appendix E. It is rather long, the repeated selection of the same option within a short time frame, which can be seen in the log, indicate difficulty in dragging.

8.6.5 The narrative comprehension task

The narrative comprehension task was used at three points during the study, see section 8.5.1. The scoring by the current author as experimenter and by the moderator is shown in Table 8-13. It can be seen that experimenter and moderator gave highly consistent scores, with the moderator being consistently slightly more generous. Participant XNX did not like this sort of task and did not answer a number of the questions put to him particularly during NCT2.

Table 8-13 NCT scores for each participant in trial 3.

Child	NCT1: The Big Box		NCT2: Handa's Surprise		NCT3: The Ice Cream	
	Scorer 1	**Scorer 2**	**Scorer 1**	**Scorer 2**	**Scorer 1**	**Scorer 2**
XDX	It was not possible to carry out this task with this child, who has very few words					
XJX	0/20		0*/20	*0*/20*	0*/20	
XEX	3/20		5/20	*6/20*	4/20	
XNX	7/20		3**/20	*5/20*	10/20	
XCX	4/20	*4/20*	3/20	*4/20*	3/20	*3/20*
XHX	7/20		7/20	*8/20*	7/20	

* XJX demonstrates *some* understanding of the stories
** XNX was upset and did not want to answer

8.7 Discussion of the results from trial 3

One of the characteristics of qualitative multiple single case modes of enquiry is that findings do not so readily fall into clear results/discussion categories as they might do with more experimental, quantitative research (Cohen, Manion & Morrison 2007; Mays & Pope 2000; Yin 1994). Thus, in this submission, some discussion occurred in the previous section along with the presentation of results. The current section focuses on an overarching discussion, keeping in mind that the purpose of the trial was to evaluate TouchStory as an assistive technology; the purpose was not to 'grade' the participants.

8.7.1 Discussion of participants' results

For three of the participants the results strongly suggest that TouchStory was effective. Participants XCX, XEX and XHX all improved in proto-narrative categories targeted for them by the adaptive function. They all appeared actively engaged in getting the correct answer at first attempt and to understand the given feedback. They each had active strategies when selecting answers, both in the first instance, and if the given answer was incorrect. The results strongly suggest that genuine acts of learning, rather than simply remembering, took place as they became more skilled with previously unseen t-stories. That is, they were able to transfer knowledge gained in one situation to another related situation where they were able to apply it appropriately.

The results for participant XEX are particularly interesting. The results show that she was not strong in any proto-narrative category in the pre-adaptive phase. The adaptive formula used in trial 2 would have identified that the participant needed to practice all proto-narrative categories (as indeed was the case), this would have resulted in either no particular focus for the adaptation or an arbitrary focus resulting from stochastic effects. Using the revised adaptive formula it is clear that the initial adaptation was on the background and then the character proto-narrative categories. This gave her a chance to focus on and improve in these categories before focusing on another proto-narrative category. In the later stages of the study the focus moved to the temporal sequence category.

The results for participant XCX are very encouraging. He is a withdrawn child who does not voluntarily interact with other children in his class at all. His strategy when faced with a simple two-piece jigsaw (knife/fork, hat/gloves) is to match on the *shape* of the jigsaw pieces, rather than to consider content of the pictures. It would seem that the design of TouchStory as a computer game (which he likes), without any additional hooks or clues which were not ‘on task’ engaged this participant in the t-story task.

Participant XHX was highly successful with TouchStory, but did not improve and indeed was not very successful with the narrative comprehension task. Indeed the learning seen with TouchStory is not reflected in an improvement in narrative comprehension, as shown by the narrative comprehension task, for any of these participants. In all cases the narrative comprehension score remains steady throughout the trial. This perhaps suggests that the cognitive gap between TouchStory and the narrative comprehension task is too large. It is also possible that the proto-narrative approach provides a finer instrument, detecting small changes.

To turn to the three participants who did not improve during the trial; these are three very different cases.

Participant XNX was actively engaged in getting the right answer in the early stages of the study. However, his performance declined during the trial due to external factors. TouchStory was (unsurprisingly) not sufficiently engaging to overcome his general disengagement. It is interesting in his case to note that the change in level of engagement seen subjectively for this participant can also be detected in changes in the on-screen activity logs for this participant. This suggests that these more detailed logs are to some degree a reflection of reality in terms of mood and engagement; it would be interesting to consider them as a basis for more detailed adaptation. Towards the end of the trial, in the third narrative completion task and in the post-adaptive phase he returned to his previous levels. The results then suggest that, for this participant, the TouchStory trial just came at the wrong time.

The case of participant XDX is interesting. In this case there was no evidence that he actually understood the TouchStory task. Nevertheless, he grew in confidence through the study, and TouchStory sessions became something he would willingly come along to; a treat when something else had gone wrong. At the end of the study, and possibly by chance, his teacher reported an increased interest in both stories and using computers.

The case of participant XJX is a lesson; TouchStory had been carefully designed not to reward behaviours other than correctly completing the task. But in this case it failed because of the final 'Thank you' screen. This is a pity as this participant did understand the task on first exposure. The strategy adopted by the experimenter, the current author, was to continue the trial as planned. It seemed cruel to take his reward away from him when predictability is so important for children with autism, and there was the possibility that he would learn, or at least become engaged, as a 'side-effect' of his going through the motions of the game to get to the final screen. Had this been a single case study a preferable strategy would have been to leave it for a while, and then re-present the t-story concept using a different screen design, so that it was not recognised, and no words on the final screen. Note that this is just one case in a total of 18 participants who used this design of TouchStory over trials 2 and 3. To provide context, creative misuse of professionally produced software was seen as commonplace during visits to the participating schools at the beginning of the study.

8.7.2 Discussion of TouchStory in use

In section 4.11 the design of TouchStory was discussed in the context of a number of questions raised by du Boulay. The results obtained in trial 3 allow some reflection regarding the specificities of the development of TouchStory in particular and software for children with autism in general. The discussion below is an updated version of the one published in (Davis et al. 2007b).

How can we engage and motivate so they are willing to attempt to learn? TouchStory, presented via a touch screen, did engage all of the participants in the sense that they were all keen to attend their sessions. In some cases the design issues may be considered effective, the participants did reason, reflect, and improve. The encoded logs described in section 8.6.4 show that some of the participants monitored their responses, 'changing their mind' in a seemingly purposeful way about their choice of option, and varying their response strategy according to the t-story. Participant XHX shows this particularly clearly. In the cases of participant XJX and participant XDX, while they did participate, they did not use TouchStory as intended. Participant XNX began by monitoring and reflecting on his answers, but adopted a stereotyped pattern of answers, which did not show evidence of monitoring or reflection, during a period when he was troubled by external events.

How can we detect what the goals of the student are (if any)? Although few of the participants spoke about their goals in any way, it seemed clear that success with TouchStory was important to some of them. A number of them made positive choices, and learned from trial and error. In the case of participant XJX the unintended goal became abundantly explicit. The difficulty lies in detecting less obvious unexpected goals.

How to maintain focus and coherence in the interaction? The simplicity of TouchStory and the nature of autism mean that once focus is obtained it is not generally lost. In the case of participant XJX the experimenter was not able to distract him from his own goal, so focus was never established. It is the author’s strong belief that any measures introduced to re-establish focus must be wholly task related.

How to make the teacher's intentions to the learner clear? The technique used was verbal explanation accompanied by physical demonstration. This was successful for 5 of the six participants. It is probable that participant XDX did not understand the task; in further work the possibility of providing more explicit feedback while retaining the current simplicity of TouchStory should be considered. Experience with participant XJX, who did understand the task and feedback at the first visit, reinforces the view that attempts to convey information, to engage and motivate the child, and to maintain focus and to render assistance, must all be directly relevant to learning task.

What makes an environment educationally rich? The results from trial 3 demonstrate that an environment may be educationally rich, adapting to and focussing on a participant’s zone of proximal development while maintaining simple and predictable behaviours. The following open questions arise. Can all of the questions discussed above be somehow incorporated in the software itself and provide support for reflection and reasoning? How can the questions themselves be adapted to each child's needs? Experience with participant XDX, showed that positive feedback might be recognised without its significance being necessarily appreciated. Can this issue be improved?

Difficulties of interpretation: The present study supports the belief that careful observation of behaviour may give some insight into the goals and understanding of a child with autism. However, the interpretation is not easy, the basis of the child's strategy in choosing an image is not, in general, known. For a typical learner these questions may be answered by questioning or inspection of verbal or written self monitoring, for learners with autism this remains an open question.

8.7.3 Discussion of the adaptive formula

The adaptive formula used in trial 3 provided an effective triage function, dividing the proto-narrative categories, for each participant, in each adaptive round, into three groups:

- those in which the participant is skilled,
- those in which the participant has some skill and would most benefit from practising (the participant's learning zone),
- those where the participant does not demonstrate skill.

This was a significant enhancement to the function used in trial 2.

However, the formula does have a 'sticking point' in the case where the number of t-stories to be presented to a participant from a given proto-narrative category has been reduced to 1 for more than 2 of the last 4 visits. When only one t-story is shown from a given proto-narrative category, the participant can only score either 100% or 0% for that category. This leads to the case analysis shown in Table 8-14, from which it can be seen that there is a very high probability that the participant will again be offered just one t-story from this proto-narrative category, regardless of whether the participant is scoring well or badly. Under the timeline for trial 3 this situation *could* arise from visit 12 onwards.

Table 8-14 Adaptive function case analysis

Case of the adaptive formula	**Outcome**
If, for the proto-narrative category, the participant has scored 100% on at least 2 of the last 4 occasions, then decrease by 1 the number to be shown in that category, to a minimum of 1.	ONE t-story will be presented from the proto-narrative category.
If the above does not apply, but the participant has scored 50% or above on at least 2 of the last 4 occasions, then increase by 1 the number to be shown in that category.	The participant *cannot* meet this condition.
If neither of the above apply, do nothing. (no change is made to the number of t-stories to be shown)	ONE t-story will be presented from the proto-narrative category.
The profile is then adjusted to present 15 t-stories, according to random numbers generated in proportion to the profile generated by application of the formula.	This provides a means of escape from the sticking point if an adjustment to increase the number of t-stories is required. However, this is specifically given a low probability of happening by the adjustment being in proportion to the profile generated.

8.8 Conclusions

From trial 3 it can be concluded that:

- TouchStory version 3 provides a engaging activity for some children with autism, which remains engaging over an extended period (20 visits). It is engaging in the face of distractions but not in the face of significant life events or an autistic child's area of special interest (as would be expected).
- Learning with respect to t-stories was seen in 50% of the participants. These participants improved in those categories which were targeted by the adaptive formula, and the learning generalised to previously unseen t-stories within those categories. This may be attributed to the longer adaptive phase (in total 20 visits were made in trial 3 compared with 12 visits made in trial 2) and the enhanced adaptive formula, which focussed on those categories which the child needed to practice, but was already doing better than guessing.

- No commensurate improvement was detected in the comprehension of real world narratives. This does not necessarily mean that there was no generalised improvement in narrative ability; it may be that proto-narratives provide a finer measure of comprehension.

8.9 Chapter Summary

Trial 3, which comprised 20 sessions with 6 participants, has been described. The structure of the trial into pre-adaptive, adaptive and post-adaptive phases was described.

The main results reported in the chapter were as follows:

- In general the participants used Touch Story as intended and results indicate that they remained actively engaged over the extended trial of 20 sessions.
- Three participants (50%) showed improvement in answering previously unseen t-stories from proto-narrative categories targeted positively by the adaptation. Thus it was concluded that generalised learning with respect to proto-narrative categories had been demonstrated.
- Worthwhile improvements in confidence were observed in one of the remaining three participants.

9. CHAPTER 9: SUMMARY AND DISCUSSION OF EXPERIMENTAL RESULTS

9.1 Summary and discussion of results

This thesis began with a presentation of the aims of the study in Chapter 1. The necessary background material was presented in Chapter 2. The concepts of proto-narratives, t-stories, and an approach to focussing on individual learning needs were presented in Chapter 3. Chapter 4 dealt with the design of a software system, called TouchStory, specifically for children with autism, which presents proto-narratives as t-stories. Chapter 5 to Chapter 8 present a series of three trials in which TouchStory was used by children with autism in order to evaluate it.

9.1.1 Summary of trial results

Results local to individual trials were discussed in the relevant chapters, and are summarised below (these points are pertinent to research questions 1 – 5 presented in section 5.1):

TouchStory, a simple, largely predictable interactive software system which presents proto-narratives as t-story games based on the closure of picture sequences, played by selecting a picture and dragging it across the surface of the screen to complete the sequence, was found to be appropriate for children with autism. In particular most participants were able to use such a system; that is they understood the task and could manipulate the touchscreen. Participants were shown to be engaged, and to enjoy using the system as intended, rather than for some other purpose, even when distractions were deliberately introduced. No adverse impact was seen, in terms of enjoyment and success, when TouchStory was compared with a similar activity in the real world.

The skills with proto-narratives which participants demonstrated while using TouchStory, in terms of choosing correct answers, were shown to reflect their skills with the narratives of everyday life in the form of published picture books.

Participants, as individuals, not as a population, found some proto-narrative categories more difficult than others.

The adaptive formula developed and used was shown to identify narrative deficits and reflect individual abilities with respect to proto-narrative categories. Thus it was possible to address individual learning needs, even though an ordering of difficulty was not known *a priori* for any individual child, and may differ among children. The results suggest that the adaptive formula used in the third trial did, for engaged participants, focus on the proto-narrative categories in which they needed practice and were most likely to succeed.

In trial 3 some of the participants (50%) were shown to learn from interactions with TouchStory in that he or she became more skilled with previously unseen t-stories from proto-narrative classes which the adaptive formula had identified that he or she needed to practice. However, no evidence was found of learning which had generalised to the real world bringing about improved skill in the comprehension and construction of the fully developed narratives encountered in everyday life.

9.1.2 Discussion of results from the trials as a series

This section is concerned not with discussing the trials as individual studies but with discussion of the three trials as a sequence in an iterative development cycle. The discussion focuses on research question 6 and research question 7 (see section 5.1 for the full list of research questions).

Research question 6: Given the difficulties of social interaction and communication faced by children with autism and those who wish to collaborate with them, is an iterative elaboration cycle over successive long term studies an appropriate software development strategy for developing software for children with autism?

Discussion of research question 6: It was established that the characteristics of autism render usual methods of requirements elicitation and software evaluation infeasible or inappropriate. The iterative elaboration cycle used in this study provided a means to involve children with autism in the software design process by observation of interactions with prototypes during successive long term trials. This was, without doubt, a time consuming process. However there are perhaps no quick fixes for involving even typically developing children in the design process; recall that Allison Druin's team found that it took six months to establish a good working relationship in an intergenerational design team. The advantages of involving children early in the design of software intended for them are evident; even more so for children with autism. The design of TouchStory is not yet complete, but the series of trials have established a 'proof of concept'. Recall that class teachers were consulted at the beginning of the design process to discuss whether, in broad terms, the t-story task was appropriate for their students. However, it was not the intention to involve them formally during the trials. Of course, consideration was given to any informal comments made by teachers or teaching assistants during the conduct of the trials. TouchStory is now at a point where it would be appropriate to involve teachers and other interested parties again in both the design of the participants' interface and the design of the experimenter/educators' interface.

Research question 7: Can an effective adaptive formula be derived by starting with a simple formula and increasing complexity only where necessary in a trial and evaluation cycle over successive long term studies?

Discussion of research question 7: The problem addressed relates to the words of Csiksenmihalyi:

'In theory, it is simple enough to make any learning enjoyable: find out what the students' skills are and what their level is, ..., and then devise limited but gradually increasing opportunities for the expression of those skills' (Csikszentmihalyi 2000, page 205).

The difficulty being that no ordering of difficulty among the proto-narrative categories was known, therefore there was no definition of 'level' and so no concept of 'increasing opportunities'. Therefore approaches to adaptation, such as those described in (Wainer 1990) were not possible.

The series of trials conducted in the study included two rounds of an iterative elaboration cycle in which an adaptive formula was developed to address these issues. In the first round of the elaboration cycle (trial 2) it was found that participants did find some proto-narrative categories more difficult than others. The simple adaptive formula used in trial 2 did, for some participants, divide the proto-narrative categories into those they could do well and those they needed to practice, and therefore for those participants it provided *gradually increasing opportunities for the expression of those skills*. It was particularly effective for those participants who needed to practice a small number of categories. However it was not effective in the case of participants who, while finding some categories more difficult than others, still needed practice in all or many of the categories. The formula did not, in the words of Csikszentmihalyi quoted above on this page, *find out what... their level is*. The formula did not focus on the participants learning needs providing *gradually increasing opportunities for the expression of those skills*, rather the selection of categories for practice was the results of stochastic effects.

In the second round of the elaboration cycle (trial 3) the adaptive formula provided a triage function. That is, for each participant in each adaptive round it divided proto-narrative categories into three groups: those the participant could do well where practice could be reduced, those he or she could best benefit from increased practice, and those in which the participant demonstrated little skill. This was found to be effective in *gradually increasing opportunities for the expression of those skills*. Thus an effective formula was derived from a simple formula in just one round of elaboration. The possibility of a sticking point, where repeated application of the formula has no further effect, was identified. The sticking point would be important if it was reached through stochastic effects rather than in response to a participant's learning needs. This could be addressed by a third elaboration cycle.

9.2 Limitations of the work and difficulties encountered

The difficulties encountered mainly arose from working with children with autism. These were overcome by the design of TouchStory and the adaptive approach used on the one hand, and by the design and conduct of the trials on the other. The main approach to difficulties faced during the trials (such as a child being upset because he had seen a banana) was to be flexible and to work with what was possible in the situation as it arose.

As a consequence of this and the previously discussed need to take a multiple single case study approach, the analysis carried out in this study is largely descriptive rather than predictive. The multiple single case study approach and the semi-regular, though rigorously collected, data sets render many statistical techniques invalid. However, it is a necessary consequence of working with children with autism in the ecologically valid way adopted and the adaptive approach taken as previously discussed, which may be summarised as:

- There were few potential participants, and these varied greatly, thus they cannot be thought of as a group representative of all children with autism.
- It was necessary to conduct sessions for individual participants (unlike a trial with a class of children).
- Sessions were unavoidably missed, in some cases because a participant was having particular difficulties on that day.
- It was not appropriate to time limit the sessions either by placing an upper or lower limit on the session length.

- Adaptation to individual participants necessarily means that the participants do not all see the same thing.

Other difficulties could be put down to general ‘events’ which beset any long term study, and again these were overcome by a flexible approach.

There is a limitation with respect to software development in that it is still a prototype. Only the interface for the participants is developed. The experimenter’s interface requires direct access to tables in a database which was quite adequate for the current author, but clearly would need to be addressed before TouchStory could become generally available.

9.3 Lessons learnt

A major lesson learned was that it is not sufficient for an adaptive formula to distinguish between those tasks which the participant can do well and those which he or she needs to practice. Ways must be found to focus the practice on his or her zone of proximal development. One may ask why could this have not been known and accommodated prior to trial 2. In one sense it could and was; it was known that the adaptive function should focus on those proto-narrative categories the participant would benefit from practising. However, recall that prior to trial 2 it was not known whether the proto-narrative approach presented as t-stories would be effective at all; nor was it known whether participants would find some proto-narratives more difficult than others. It is only because the proto-narrative approach was effective, and individual participants did have differential learning needs across the proto-narrative categories, that one is tempted to ask the question posed above. So that, while there is a lesson to be learned about the adaptive formula, the way in which the adaptive formula was derived was shown to be valid.

A second lesson is that it is probably impossible to create one learning environment suitable for all children with autism. Although TouchStory was designed for children with autism from the outset, in that it was planned that the TouchStory environment would adapt to individual learning needs, and that the interface would be simple and the rewards ‘on task’, some participants did not comprehend the task and there was one participant for whom the rewards were counter-productive. This perhaps shows the need not only for an adaptive but also a tailorable environment. In this matter it would be useful to involve teachers and other interested professionals as mentioned above in section 9.1.2.

9.4 Guidelines for creating interactive environments for children with autism

This section presents guidelines, arising from the successes and limitations of this study, to aid future researchers in developing interactive software environments for children with autism using long term observation as part of an evaluative methodology. An overview of the guidelines, which are a development of the design framework presented in Figure 3-10, is presented in Table 9-1. The guidelines pertain not only to the design of interactive software but also to the design and conduct of observational trials and sessions. For this reason two aspects of autism are added to the user group characteristics of Figure 3-10, these being first that autism is primarily a social disability and second that children with autism may work to their 'own agenda'. By this is meant that the child's own state of mind might over-ride any interest in an activity he or she is being invited to engage in (explicitly or implicitly) by the experimenter. Last, further guidelines arising from the methodology rather than the characteristics of the participants are included. In Table 9-1 the column *aspects of autism* lists the characteristics just discussed, the column *trial guidelines* refers to those guidelines which relate to the design of the trial as a whole, the column *session guidelines* refers to those guidelines which relate to the design and conduct of individual sessions, and the column *interface & software guidelines* refers to those guidelines which relate to the interaction interface and to software functionality. A number of guidelines apply in more than one context and to more than one aspect of autism, so that the same guideline may be referred to in more than one row and / or column. The guidelines themselves are presented after Table 9-1.

Table 9-1 Guidelines for developing interactive software for children with autism

Aspects of autism	**Trial Guidelines**	**Session Guidelines**	**Interface & Software Guidelines**
Autism is primarily a social disability	Guideline 1 Guideline 4 Guideline 9	Guideline 8 Guideline 9	
Children with autism prefer routine and predictable, reliable environments and certainty, and find it difficult to be flexible and accommodating	Guideline 4 Guideline 6	Guideline 4 Guideline 8 Guideline 9 Guideline 10 Guideline 11 Guideline 12	Guideline 14 Guideline 16
Children with autism have a tendency to repetitive behaviours and may have powerful special interests or fears	Guideline 1	Guideline 12 Guideline 20	Guideline 14 Guideline 15 Guideline 13 Guideline 17 Guideline 18 Guideline 20
Children with autism may have particular sensory sensitivities, and may be visual learners and thinkers	Guideline 1	Guideline 12	Guideline 14 Guideline 15
Children with autism tend to look for meaning in matters of detail (local cohesion)		Guideline 12	Guideline 13 Guideline 14 Guideline 15
Children with autism may find failure very debilitating		Guideline 10	Guideline 20
Children with autism may have their 'own agenda'	Guideline 5	Guideline 11	Guideline 13 Guideline 15
Children with autism may not be able to communicate verbally, use a mouse or keyboard, or understand remote object reference and some forms of abstraction	Guideline 1 Guideline 2		Guideline 2
Autism independent guidelines	Guideline 3 Guideline 7		Guideline 19

The guidelines referred to in Table 9-1 are as follows:

Guideline 1. There is no substitute for observing potential participants in a number of environments before detailed ideas are generated.

Guideline 2. Check skills which will be *relied* upon in the study, examples being the ability of potential participants' to use a keyboard, mouse, remote control, etc. Similarly, if participants are to answer questions, confirm that potential participants a) speak and b) are not made anxious by the kind of social interaction that surrounds the asking and answering of questions. If an inclusive approach is to be taken to participant selection then alternative means of interaction and communication should be considered.

Guideline 3. Ensure parents and guardians are fully informed of the intended study, for example by producing leaflets, but keep parental consent forms simple to avoid unclear or ambiguous returns.

Guideline 4. The trial design should allow both the experimenter (if present at sessions) and the software become an established part of the participants' routines.

Guideline 5. The trial design or analysis methodology should recognise that participants may miss some sessions for a variety of reasons and may be upset or focussed on some other matter during some sessions.

Guideline 6. Plan for the end of the trial. Consider how it will be drawn to an end and what (if anything) will be left with the participants at the end of the trial. This is particularly important in the case of autism as the participants find it difficult to adapt to changes in routine. Some TouchStory participants appreciated photographs of themselves using TouchStory.

Guideline 7. View the accommodation which is to be used for sessions before the trial begins to plan seating arrangements, camera angles etc. At this stage abstract plans regarding room layout and use are made concrete, and, if necessary, modified in the light of actual physical constraints.

Guideline 8. Consider who will conduct the sessions, or tasks within sessions, and value the time given by people who contribute to the running of sessions. The experimenter will be familiar with the concepts of the trial, but time must be spent to allow participants to become comfortable with the experimenter; alternatively participants may be more comfortable with someone they know better and that person may have greater skill and experience in interacting with children with autism, but the experimenter loses some control of the session, and time must be spent by that person not only in conducting the session but also in understanding what is being asked of them by the experimenter.

Guideline 9. Consider how many people will be in the room during sessions, what their roles are, and whether the number of people will overwhelm the participant.

Guideline 10. Have regard for the value of the participants' time and also attention span and comfort when planning sessions. Avoid over-taxing participants with overlong sessions and be prepared to end sessions early.

Guideline 11. The plan for each session should be flexible; on any particular day accommodation may be changed to another room, or a participant may be unsettled or uncooperative.

Guideline 12. Prepare the room for each session moving incidental distraction out of sight, such as items might alarm the child or be of greater interest than the intended activity; ducks and words, dogs and doors, food, spectacles, cameras and laptops were encountered as special interests or fears in TouchStory trials.

Guideline 13. All aspects of the software interface, for example feedback, or devices to attract attention or signal the structure of the interactive session should re-enforce the intended task.

Guideline 14. Keep the environment, that is, the room, and the software interface, simple with low differentiation between local and global cohesion.

Guideline 15. Be aware of sensory sensitivities. Use a simple palette in the software interface and avoid *unnecessary* sounds or animations. Similarly be aware of sensitivities to the equipment or other aspects of the physical environment.

Guideline 16. Recognise that children with autism vary greatly in their abilities and interests, and find it difficult to be flexible and accommodating. Build flexibility into the sessions and software interface through adaptation and / or customisation.

Guideline 17. Consider whether you will accommodate special interested and fears in the software interface and functionality.

Guideline 18. Be aware of repetitive behaviour patterns. Consider the balance of control between the system and participant. Where appropriate design out the possibility of negative repetitive behaviours.

Guideline 19. Record keeping: Build in data logging facilities from the design stage. Even if there is no plan for the software to be adaptive, such logs can give insight into the way in which the software was used. Plan for record integration: if hybrid data (for example software logs and video sequences) are collected then consider, at the design stage, whether and how it is to be integrated. If it there is an intention to use third party software for integration or evaluation then consider compatibility issues between the third party software and the logs at the design stage.

Guideline 20. Remember that children with autism can find failure debilitating. Both the conduct of the sessions and design of the software should present the participant with positive ways forward.

10. CHAPTER 10: CONCLUSIONS AND OUTLOOK

In this final chapter the original hypotheses are revisited and the conclusions for the study as a whole are presented, leading to a statement of the contribution to knowledge that has been made by this thesis. This is followed by a discussion of a number of possible directions for future work. The chapter ends with concluding remarks from a personal perspective.

10.1 Preamble

It is interesting at this point to revisit the first publication regarding this work which was a poster displayed at the 7th European Congress on Autism held in Lisbon in 2003 from which the following quotations are taken: "*Our premise 'Narrative structure is fundamental to the perception, creation and communication of meaning in social interaction'*" quoting from (Dautenhahn 2002). "*Our aim is to develop interactive software which can be used in helping children with autism to develop narrative skills*" (Davis et al. 2003). This premise and aim remain unchanged; TouchStory has taken a first but significant step towards our goal.

10.2 Conclusions from the study

Recall from section 1.3 that the overarching hypothesis of this thesis (H0) is that '*it is possible to help children with autism to improve their narrative skills by breaking down narrative into proto-narrative components and addressing these components individually. Further, the presentational and logging facilities possible in a software system render it feasible to reflect individual abilities, and thus address individual learning needs*'.

The approach taken was to run a series of trials to evaluate this hypothesis. The software development strategy was iterative, with observation and analysis of sessions informing the subsequent development of TouchStory. The design principles used in the development of TouchStory reflect both the ideas of Csikszentmihali and Vygotsky on engagement and learning in general, and the needs and characteristics of children with autism in particular. Individual learning needs were addressed by an adaptive formula applied to each participant's TouchStory profile. The approach taken to adaptation was to trial and evaluate a simple formula and increase its complexity as necessary between trials.

By the beginning of the third and final trial (see Chapter 8) the overarching hypothesis had been refined to four simpler hypotheses and an outstanding research question.

Hypothesis 1: A simple and largely predictable interactive software system such as TouchStory, presented using a touch screen with draggable pictures, is appropriate for children with autism.

From trial 1 it can be concluded that the design features used in TouchStory version 1 provide an appropriate interaction medium and engaging activity for children with autism. The presentation of the game as a computer-based activity frees the attending adult from the game management task, allowing her to give greater attention to the participant. The participant is able to complete games in a shorter time giving a more focussed session. From trial 2 it can be concluded that the design features used in TouchStory version 2 provide an appropriate interaction medium and engaging activity for some children with autism, which remains engaging over an extended period (12 visits). TouchStory version 3 provides an engaging activity for some children with autism, which remains engaging over an extended period (20 visits). It remained engaging in the face of interruptions and distractions, but not in the face of life events or in conflict with an autistic child's area of special interest (as would be expected).

Hypothesis 2: Children with autism, who are able and willing to use TouchStory, will find some proto-narrative categories more challenging than others. From both trial 2 and trial 3 it can be concluded that children with autism do have individual abilities and learning needs with respect to the proto-narrative categories presented in TouchStory.

Hypothesis 3: Over multiple exposures, repeated application of a simple adaptive formula based on a participant's previous success will tailor the set of t-stories presented by TouchStory towards the learning needs of an individual participant. From trial 2 it can be concluded that the adaptive formula used in trial 2 distinguished between those proto-narrative categories which a participant did well, and those which he or she needed to practice. However, it was less successful in addressing learning needs where a participant did not do 'well' in any category, but was nevertheless was more successful in some categories than others. In trial 3 it was shown that learning was seen in 50% of the participants who improved in the proto-narrative categories addressed by the adaptive formula. This reflects to the longer adaptive phase (than in trial 2), the enhanced adaptive formula, which focussed on those categories which the participant could do quite well but not very well, and improved experimental design where new t-stories were introduced in a more controlled way. Experience during these trials also showed that the presentational and logging facilities possible in a software system render it feasible to reflect individual abilities, and thus address individual learning needs.

Hypothesis 4: Participants' overall success with TouchStory relates to their comprehension of real world narratives presented as picture stories. From trial 2, which had 12 participants it can be concluded that as a group, participants' overall success with TouchStory correlates with their comprehension of real world narratives presented as picture stories as show by the narrative comprehension task based on the work of Paris and Paris described in section 5.6.

The open research question: Does breaking down narrative into proto-narrative components and addressing these components individually help children with autism to improve their real world narrative skills, either actually or as rendered via coping strategies? While learning was seen in trial 3 with respect to t-stories no commensurate improvement was detected in the comprehension of real world narratives. This does not necessarily mean that there was no general improvement in narrative ability; we may speculate that proto-narratives provide a finer measure of comprehension. Ways forward are discussed in section 10.4.

Overall then it can be concluded that:

- A straightforward computer based game, presenting a simple interface and predictable behaviours allowing the enjoyment of skills already mastered while gradually increasing the level of challenge, can provide an engaging activity for children with autism whilst freeing the attending adult to concentrate on the needs of the child rather than the management of the game;
- The proto-narrative concept is effective in identifying narrative deficits in some children with autism, and can form a basis for learning;
- A simple adaptive formula applied to a participant's previous results can target the learning zone of individual participants with respect to proto-narrative categories. This is rendered feasible by a computer-based approach which first, by managing the presentation and layout of the t-stories makes it possible for participants to complete a sufficient number of t-stories, and second, by software logging gives a complete and accurate record as a basis for adaptation;
- Iterative development and evaluation using observation in extended studies provides a means of including children with autism in the development of software.

10.3 Original contribution to knowledge

The design of TouchStory was based on the needs and characteristics of children with autism and addresses the narrative deficit found in children with autism. The results from this study provide the following contributions to knowledge:

Conceptual contribution: The novel proto-narrative concept introduced in this thesis was found to be effective in identifying specific narrative deficits in some children with autism, and was shown to form a basis for learning;

Computational adaptation: The novel concept of an adaptive formula was shown to effectively target the learning zone of individual participants with respect to proto-narrative categories. This successfully addressed the challenge that no ordering of difficulty was known *a priori* among the proto-narrative categories for any given participant. Repeated application of the adaptive formula during long term studies gradually increased the level of challenge presented to each participant, while at the same time maintaining predictability and offering opportunities to express skills already mastered, thus providing a comfortable and enjoyable experience for children with autism. The formula was shown to be sensitive to changing learning needs while being insensitive to (i.e. ignoring) odd mistakes and atypical sessions. An iterative elaboration cycle, beginning with a simple adaptive formula and increasing its complexity where necessary over successive long term studies, was shown to be an effective development strategy.

Contribution to software development: The successful cycle of development in this study has shown that iterative development combined with long term trials is an effective and inclusive means of developing software for children with autism. It provides an ecologically valid route to including children with autism in the processes of requirements elicitation and the design of software artefacts. This successfully addresses the challenge that consulting children with autism as part of a child centred design process is difficult. Such children are necessarily not socially inclined, may have no productive language, and are typically resistant to change and novelty.

Contribution to assistive technology: It remains an open question whether addressing proto-narrative components can make a direct contribution to improving the everyday lives of children with autism by improving their real world narrative skills, either actually or as rendered via coping strategies. However this study has made a small but significant contribution to assistive technology in the case of autism by showing a route to universal access and inclusive design.

The contributions as a whole: The conceptual contribution and the contribution to computational adaptation were rendered feasible by a computer-based approach. The contributions to software development and assistive technology provided a framework in which to develop a computer based system such that it was accessible to children with autism both in terms of interface and behaviour.

10.4 Future work

The work described here documents a series of prototypes working towards an interactive software system, designed for children with autism, with the intention of improving their skills at recognizing and completing proto-narrative sequences in order to improve their comprehension and construction of everyday narratives. As discussed this is a very challenging domain and not all aspects could be covered in full within the scope of this thesis, thus further work could be undertaken along a number of dimensions.

The development and deployment of TouchStory. TouchStory is a prototype, the trials have shown that it would be appropriate to develop TouchStory as a complete system, such that it could be distributed to a wider population. At this point, now that the proto-narrative approach has been shown to be effective and there is demonstration software available, it would be appropriate to seek input from representatives of the multi-professional teams who work with children with autism. Input would be sought not only on TouchStory *per se*, but also on extensions to TouchStory such as those discussed above. It would also be necessary to address a number of outstanding issues which include development of the interface for the experimenter (or teacher or other professional) so that t-stories are simpler to set up and any necessary amendments to results log made via a suitable interface rather than by direct interaction with the database as at present. Professional preparation of t-stories would be desirable, with particular attention to the visual complexity of the t-story corpus, ensuring as far as is possible that each proto-narrative category is adequately represented at each level of visual complexity. Further, consideration should be given to the types of panel-to-panel transitions used in the t-stories. Further work could build on the concepts introduced in this thesis to bridge the gap between an understanding of proto-narratives as presented by TouchStory and an understanding of real world narratives. A number of computer based tasks could be designed, for example, a TouchStory-like game could be devised in which all (or some number) of the panels are movable, and the participant is asked to arrange them into a story. The task itself would require low social mediation as there is no need for the participant to answer verbal questions; the difficulty would be in conveying to the participant what was expected. Of particular interest would be sequences of photographs of the participant involved in everyday activities, thus relating to the narratives of everyday life.

An alternative participant interface would be needed if TouchStory was to be used in cultures which use an order of presentation other than left to right.

The extent to which screen interaction captures the dynamics of a session. TouchStory produces two software logs, a simple log which is taken as the basis for adaptation, and a more detailed log of on-screen activity. The latter was analysed to gain an understanding of participants' strategies when choosing answers, in particular when a participant had just given an answer which was wrong. The results strongly suggested that these logs were effective in reflecting some measure of participants' engagement with the task. It would be interesting to compare the text logs with the video sequences in order to determine how effective the logs are at capturing the engagement and reflection of participants during sessions, and whether this forms the basis adaptation to behaviour of the participant within an ongoing session. Currently the 'Observer' help team (Tracksys 2008) are looking to see if there are ways of relating the current software logs with the video sequences. However future versions of TouchStory could be designed with the requirements of specific analytical software, such as Observer, in mind.

The application of the adaptive approach to other domains. The adaptive approach used in this study has been shown to be effective in the TouchStory context. It is reasonable to suppose that the effectiveness of the approach will generalise to other contexts and aspects of assistive and educational technology for children with autism.

10.5 Personal remarks

Conducting this study in part-time mode, for the most part while working as a senior lecturer was a richly varied but challenging experience. Without doubt the variety was part of the appeal, incorporating as it did the very different activities of, for instance: the study of theoretical aspects (e.g. of narrative), the creative processes of designing software for a special group and designing and creating the t-stories, java and database programming, gaining some understanding of autism and interacting closely with children with autism over an extended period. The study also opened new areas of scholarly exchange and development; I was proud to present papers at a number of international conferences on assistive technology where it was rewarding to receive feedback from, and share ideas with, researchers and practitioners from many disciplines.

The last word is left to Bruner: '*for all that narrative is one of our evident delights, it is a serious business*' (Bruner 2002, page 89).

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APPENDIX A: GLOSSARY

Term	Definition
Aurora	A long term research project 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'.
Autism	Autism is a lifelong pervasive developmental disorder affecting social ability. Although people with autism form a diverse group they all exhibit impaired social interaction and social communication, and have a limited range of imaginative activities, this is sometimes referred to as the 'triad of impairments'.
Closure	In comics, the process of mentally constructing a continuous reality from adjacent static pictures. The word is used in this sense in this thesis.
Gutter	The space between panels in a picture narrative or comic. The active process of narrative comprehension combines the happenings in the panels with assumed happenings in the printed gutter.
Long term study	This term has been used to indicate a study in which data is collected at a number of time points over an extended elapsed time (in this thesis trial 2 had 12 such points and trial 3 had 20 such points, both studies took place over several months).
Over-reading	The process of incorporating material which is not signified in the narrative discourse during narrative comprehension. Some over-reading is inevitable and necessary as omissions from the narrative discourse are unavoidable (see gutter).
Panel	Panels contain the pictures in a comic. Thus a comic consists of a number of panels (sometimes called panes), in a deliberate order, and with a deliberate spacing (see gutter).
Proto-narrative	A term introduced in this thesis to mean a sequence presenting one aspect of narrative (for example the characters or the setting). This allows consideration of just one dimension of narrative comprehension in contrast to the many dimensions of the fully developed narratives of everyday life.
TouchStory	An interactive software game devised and created in this study which is a vehicle for presenting t-stories (see below).
t-story	A term introduced in this thesis to mean an instance of a proto-narrative or simple picture story with a particular form of presentation as a game.

APPENDIX B: PUBLICATIONS RESULTING FROM THIS WORK

Publications arising directly from the work described in this thesis

Davis M., K. Dautenhahn, C.L. Nehaniv, S.D. Powell (2003). Coherent Worlds - the Role of Narrative in the Creation of Meaning. *Proceedings of the 7th International Autism-Europe Congress*, Lisbon: pp 399-400.

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Davis M., N. Otero, K. Dautenhahn, C.L. Nehaniv, S.D. Powell (2007b). Creating a Software to Promote Understanding About Narrative in Children with Autism *Proc. 6th IEEE International Conference on Development and Learning (ICDL 2007)*, Imperial College, London: pp 64-69.

Publications informed by the current work

Watson S., N. Vannini, M. Davis, S. Woods, M. Hall, L. Hall, K. Dautenhahn (2007). Fearnot! An Anti-Bullying Intervention: Evaluation of an Interactive Virtual Learning Environment. *Proceedings of AISB'07*, Newcastle University, Newcastle upon Tyne, UK, SSAISB pp 446-452

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APPENDIX C: CORRESPONDENCE WITH SCHOOLS

Parental consent form

Adaptive Systems Research Group

Department of Computer Science
University of Hertfordshire
College Lane
Hatfield
Hertfordshire
AL10 AB
(Dr. Dautenhahn) Tel: 01707 284333
(Megan Davis) Tel: 01707 284372

Dear Parent/Carer

The University of Hertfordshire is working on a project called "Aurora" which aims to develop robotic and interactive software systems that can be used in schools, in particular with children with autism, to aid communication and social skills. As part of this project we are looking at software games that encourage and promote storytelling. Initially we will be using physical objects such as laminated picture cards together with a software game using a touch sensitive screen.

As part of this research, we need to observe a variety of non-autistic as well as autistic children in order to find out about general interaction styles of children who are playing with our system. We would like to make clear that this will not involve any psychological testing or assessment of the children, and the children will not be named. Our goal is rather to test the suitability of the software to help us to improve the development of an appropriate tool. The children will not be left unsupervised and safety factors are carefully considered. For research purposes we require to videotape the tests (and possibly photos will be taken). The evaluation and real-world testing of the software is a vital part of its development and we appreciate your support.

We would be grateful if you could complete the section at the bottom of this letter and return it to ……. If you have any questions about the project or the testing session please do not hesitate to contact us, details above.

Professor Kerstin Dautenhahn, (Principal Investigator of the Aurora Project)

Megan Davis, Senior Lecturer

With respect to the Aurora project:

I consent to allow my child …………………………………………………..:

- ∗ To take part in the current trial sessions which use laminated picture cards and a software game using a touch sensitive screen [ ]
- ∗ To be videotaped during the trials [ ]
- ∗ I give permission for photographs of my child taken during trials to be used in scientific publications [ ]
- ∗ I give permission for video sequences of my child playing with the cards and software to be used in scientific presentations of the project [ ]

It is also possible that further trials may occur within the same project.

- ∗ I am willing to allow my child to participate in future trials, you need not ask me again [ ]

OR

- ∗ Please ask me again nearer the time if you would like my child to participate in future trials [ ]

(* Please tick boxes if you agree).

Signature……………………………………………. Date……………………………………

Please return to …………..

Thank you.

Schools Questionnaire

TouchStory: About the children   Child's name ……………………………

About using computers
Does this child generally enjoy using computers?
Please rate this on a scale 0 1 2 3 where 0 means not at all and 3 means very much ____ .
Additional observations:

Can he/she use a mouse?
Please rate this on a scale 0 1 2 3 where 0 means not at all and 3 means very well ____ .
Additional observations:

If known, please say what techniques/software have been used to teach the child how to use a mouse, and how readily he/she acquired the skill.

About motor skills
Does this child generally have difficulty with manual dexterity?
Please rate this on a scale 0 1 2 3 where 0 means considerable difficulties and 3 means no troubles with dexterity ____ .
Additional observations:

About narrative
Does this child like stories?

If so what sort of stories does she/he like?

Does he/she seem to understand the emotions and motives of the characters in a story?

Does she/he like to tell imaginative stories? If so, what type?

About the child
So that I can understand my findings in the context of the child's usual behaviour, please can you give me an idea of the behaviour patterns you would expect from this child in everyday life at XXX, especially any behaviour suggestive of autism?

APPENDIX D: THE NARRATIVE COMPREHENSION TASK

This appendix shows the questions and score sheets used in the narrative comprehension tasks based on the work of Paris and Paris [1] which were used in trials 2 and 3.

Narrative comprehension task in trial 2

The narrative comprehension task used in trial 2 was based on the book A Boy, A Dog, and A Frog [2]. The prompt sheet to be used by the questioner during the prompted comprehension task is shown *Appendix D Table 1*. The score sheet for the prompted comprehension task is shown in *Appendix D Table 2*.

Appendix D Table 1: Narrative Comprehension Task Questions

question number	focus	page	question
Q1	characters	closed	Who is in this story?
Q2	setting	closed	Where does the story happen?
Q3	initiating event	3	Tell me what is happening at this point in the story. Why is it important?
Q4	causal inference	7	What is the boy doing? Why?
Q5	problem	8	If you were telling the story what would you say is happening now? Why did this happen?
Q6	feelings	10	What do you think frog is feeling in this picture? Why do you think so?
Q7	dialogue	11	What do you think they are saying here? Why?
Q8	outcome resolution	15	What is happening here? Why is this happening?
Q9	prediction	16	This is the last picture in the story. What do you think happens next? Why do you think so?
Q10	theme	closed	Now you have looked at this story, what would you say if your friend was going fishing?

Appendix D Table 2 Narrative Comprehension Task Rubric

Child's Name Particiapant's name to go here **Rater** Rater's name to go here

	What to look for:	**un-prompted**	**simple prompt**	**repeated prompting**
Q1	dog, frog, boy (2 points) any 2 (1 point) none or 1 of above (0 point)			
Q2	understanding of multiple settings (2 points) only one setting (1 point) no appropriate setting (0 points)			
Q3	response links 'tripping' with other relevant story info (2 points) identifies tripping over branch (1 point) fails to mention the boy trips over the branch (0 point)			
Q4	an appropriate inference using events from multiple pages (2 points) appropriate inference at the page level (1 point) no appropriate causal inference (0 point)			
Q5	identifies he has caught the dog, and links with he meant to catch the frog (2 points) identifies he has caught the dog (1 point) does not identify has caught the dog, or is not appropriate (0 points)			
Q6	identifies frog is sad and links to other pages or events (2 points) identifies frog is sad (1 point) does not identify frog is sad (0 points)			
Q7	appropriate dialog linking with other pages or events (2 points) appropriate dialogue (1 point) response not about dialog or not appropriate (0 points)			
Q8	identifies they are in the bath and frog joins them, and refers back to, they fell in the pond, or the frog was sad (2 points) identifies that they are in the bath and frog fails to mention these (0 points)			
Q9	prediction relates to previous pages or actions, e.g. they all go fishing tomorrow (2 points) prediction related to the page, e.g. they get dry (1 point) no prediction (0 points)			
Q10	incorporation of multiple events to form narrative (2 points) simple response from one aspect of the story (1 point) no indication of understanding of what the story was about (0 points)			

Narrative comprehension tasks in trial 3

In trial 3 the narrative comprehension task was used at three points using the following books: The Big Box [3], Handa's Surprise [4], and The Ice Cream [5]. The questions used in all three tasks are given in *Appendix D Table 3*. Note that this table allows the reader to compare the questions for the three tasks and to compare them with the questions published by Paris and Paris. It does not give an order of presentation for the questions as this varies depending on the story. Notice that some of the questions have been altered from the Paris and Paris originals, for example the question about the setting '*Where does this story happen*?' tended to get a response indicating '*in the story-book'* from participants with autism. Some questions were shortened to a length more appropriate for the participants.

Appendix D Table 3: Questions for all three prompted comprehension tasks

Question type	**Example from Paris and Paris [1]**	**The Big Box**	**Handa's Surprise**	**The Ice Cream**
Preparatory question	Have you seen this book before? Is it a new story?	Have you seen this book before? Is it a new story?	Have you seen this book before? Is it a new story?	Have you seen this book before? Is it a new story?
Questions about things explicit in the story				
Character	1. Book Closed. Who are the characters in this story?	Can you remember who is in this story? Anyone else?	Can you remember who is in this story? Anyone else?	Can you remember who is in this story? Anyone else?
Setting	2. Book Closed. Where does this story happen?	Can you remember where the story was set? Anywhere else?	Can you remember where the story was set? Anywhere else?	Can you remember where the story was set? Anywhere else?
Initiating Event	3. [Pg.10] Tell me what happens at this point in the story. Why is this an important part of the story?	[pic1] What is happening here, Why is it important in the story?	[pic1] What is happening here? Why is it important?	[pic2] What is happening here? Why is it important in the story?
Problem	4. [Pg.12]: If you were telling someone this story, what would you say is going on now? Why did this happen?	[pic3] If you were telling the story what would you say is happening now? Why is that a problem/ important?	[pic3] What is happening here? Why is it a problem?	[pic4] What is happening here? Why?
Outcome Resolution	5. [Pg.18] What happened here? Why does this happen?	[pic5] What is happening here? Why is it happening?	[pic12] What is happening here? Why is it important?	[pic5] What is happening here, what is the man saying, what is the boy feeling?

Question type	**Example from Paris and Paris [1]**	**The Big Box**	**Handa's Surprise**	**The Ice Cream**
Questions about things implicit in the story				
Feelings	1. [Pg.6]: Tell me what the people are feeling in this picture. Why do you think so?	[pic4] What are the children feeling is this picture? Why?	[pic2] How do you think this girl feels in this picture?	[pic3] What is the boy feeling in this picture? Why?
Causal Inference	2. [Pg.8]: Why did the family get the robot?	[pic4] What is the mother doing in this picture? Why?	[pic10] What is happening here? Why is it happening?	[pic3] what is the girl doing here/ why is it important?
Dialogue	3. [Pg.16]: What do you think the people would be saying here? Why would they be saying that?	[pic2] What do you think these people might be saying? …anything else? .. why?	[pic 11] What are the girls saying now? Anything else?	[pic1] What are the boy and the dad saying here? Anything else?
Prediction	4. [Pg.18] This is the last picture in the story. What do you think happens next? Why do you think so?	[pic5] This is the last picture in the story, what do you think happens next? .. anything else?	[pic12] This is the last picture in the story, what do you think happens next?	[pic5] This is the last picture in the story, what do you think happens next?
Theme	5. Book Closed. In thinking about everything that you learned after reading this book, if you knew that your friend's dad was bringing home a robot for his family, what would you tell the dad to help him so that the same thing that happened in this story doesn't happen to him? Why would you tell him that? (replacement words: advice, warn)	Now you have seen this story, what would you say to someone who was going to build a playhouse?	Now you have seen this story, what would you do if you were taking some fruit to a friend?	Now you have seen this story what would you say someone was going to buy an ice cream at the beach

11. Appendix D Table 4 score sheets for narrative comprehension tasks in Trial 3

	The Big Box: score sheet for narrative comprehension task					
0	Have you seen this book before? Is it a new story?	Yes		No		Additional comments
1	Can you remember who is in this story? Anyone else?	Any two characters, including delivery man		Any 4 or more including the delivery man – do not score if the child mentions two or more characters who are not in the story		
2	Can you remember where the story was set? Anywhere else?	Simple setting e.g. garden		More detailed settings e.g. mentioning the playhouse as well as the garden		
3	[pic1 IE] What is happening here? Why is it important?	The man is delivering the fridge.		Important because he brings the box which they will use.		
4	[pg 2 D] What do you think these people might be saying? … anything else? … why?	Reference to the picture, e.g. we have nearly finished		Dialog which alludes to parts of the story seen on other pages. Look for discrimination, e.g. do not score if the child tells the whole of the story		
5	[pic3 Prob] If you were telling the story what would you say is happing now? Why is it a problem / important?	Reference to rain		Appreciation of why the rain is important. Look for discrimination, as above.		
6	[pic4 CI] What is the mother doing here? … why?	An answer that can be seen from the picture		Appreciation of the cause – e.g. she has come to get them in because they will get wet if they stay in the playhouse (not just because it is raining)		
7	[pic 4 F] What are the children feeling in this picture? .. why?	Appropriate emotion (sad, disappointed etc)		Appreciation of why the emotion is felt with reference to the story, the playhouse which they have made is now ruined.		
8	[pic5 OR] What is happening here? Why is it happening?	Dad is putting up a tent		Reference to the rest of the story, e.g. the tent will withstand the rain.		
9	[pg12 Prediction] This is the last picture in the story, what do you think happens next?	Simple reference to the picture or daily life		Predictions that call on previous parts of the story.		
10	Now you have seen this story, what would you do if you were taking some fruit to a friend?	Simple theme using one aspect of the story.		Theme draws on multiple parts of the story.		

	Handa's Surprise: score sheet for narrative comprehension task					Additional comments
0	Have you seen this book before? Is it a new story?	Yes		No		
1	Can you remember who is in this story? Anyone else?	Any two characters, including Handa.		Any 4 or more including both Handa and her friend.		
2	Can you remember where the story was set? Anywhere else?	An appreciation of the setting , mentioning one place (e.g. Africa)		An appreciation of multiple settings as relevant to the story (e.g. the journey, the field with the goat, the friends village) at least 2 mentioned.		
3	[pic1 IE] What is happening here? Why is it important?	Appreciation of what can be seen from the picture. Putting fruit in a basket.		Appreciation picture in context of story, e.g. different fruits to take to her friend.		
4	[pg 2 Feelings] How do you think this girl feels in this picture? Why?	Any appropriate emotion, happy, proud , excited		Any understanding of why the emotion might be felt.		
5	[pic3 Prob] What is happening here? Why is it a problem?	What can be seen. The monkey is taking the banana.		Appreciation of why this is a problem in the story; e.g. Handa's friend will now not get a banana.		
6	[pic10 CI] What is happening here? Why is it happening?	Appreciation of what can be seen; e.g. the goat crashing into the tree, fruit into the basket.		Appreciation of the cause – the rope breaking and the goat crashing into the tree causes the fruit to fall.		
7	[pg 11 Dialog] What are the girls saying now? Anything else?	Suitable dialog from the picture, e.g. 'Hello, I've got some fruit'		Dialog specific to the story, referring back to other pictures e.g. "Look what I have brought you".		
8	[pic12 OR] What is happening here? Why is it important?	The girls are eating the fruit.		Reference back to the story e.g. that the original fruit had been stolen.		
9	[pg12 Prediction] This is the last picture in the story, what do you think happens next?	Simple reference to the picture, e.g. they eat some fruit and then they play.		Predictions that call on previous parts of the story.		
10	Now you have seen this story, what would you do if you were taking some fruit to a friend?	Simple theme using one aspect of the story.		Theme draws on multiple parts of the story.		

	The Beach: score sheet for narrative comprehension task					Additional comments
0	Have you seen this book before? Is it a new story?	Yes		No		
1	Can you remember who is in this story? Anyone else?	Any two characters.		4 or more characters, including characters crucial to the story such as the ice cream man, the girl with a ball, or the man who the ice cream fell on. No 'guessing' extraneous characters		
2	Can you remember where the story was set? Anything else about it?	An appreciation of the setting , mentioning one place		An appreciation of setting as relevant to the story, e.g. near the ice cream van		
3	[pic1 D] What are the boy and dad saying here?	Appreciation of what can be seen from the picture. e.g. asking if he can have an ice cream.		Relates to the rest of the story, e.g. be careful, or don't run		
4	[pic2 IE] What is happening here?	The boy is running		Appreciation that he is running to the ice cream van		
5	[pg 3 CI] What is the girl doing here? Why is it important?	Appreciation of what can be seen from the picture. e.g. twirling the ball.		Appreciation that this is the cause of the problem.		
6	[pic3 F] What is the boy feeling ? Why?	Appropriate feeling e.g. happy		Appreciation of why, he is looking forward to eating his icecream		
7	[pic4 P] What is happening here? How does he feel?	Falling over, loosing ice cream		Reference to other parts of the story.		
8	[pic5 OR] What has happened here? How does he feel?	Ice cream on the man's head		Answer refers to other parts of the story, e.g. the man was lying in the sun.		
9	[pic5 Pred] This is the last picture in the story, what do you think happens next?	Simple reference to the picture.		Predictions that call on previous parts of the story, or develop outcome resolution		
10	Now you have seen this story, what would you do if you were taking some fruit to a friend?	Simple theme using one aspect of the story.		Theme draws on multiple parts of the story.		

Narrative comprehension task bibliography

1. Paris, A. and S.G. Paris, *Assessing Narrative Comprehension in Young Children.* Reading Research Quarterly, 2003. **38**(1): p. 36-76.
2. Meyer, M., *A Boy, A Dog, and A Frog*. 1978: Puffin Pied Piper.
3. Hunt, R. and A. Brychta, *The Big Box*. 1991: Oxford University Press.
4. Browne, E., *Handa's Surprise*. 1994: Walker Books.
5. Hunt, R., *The Ice Cream*. 2008: Oxford University Press.

APPENDIX E: TRIAL 3 COLLECTED RESULTS

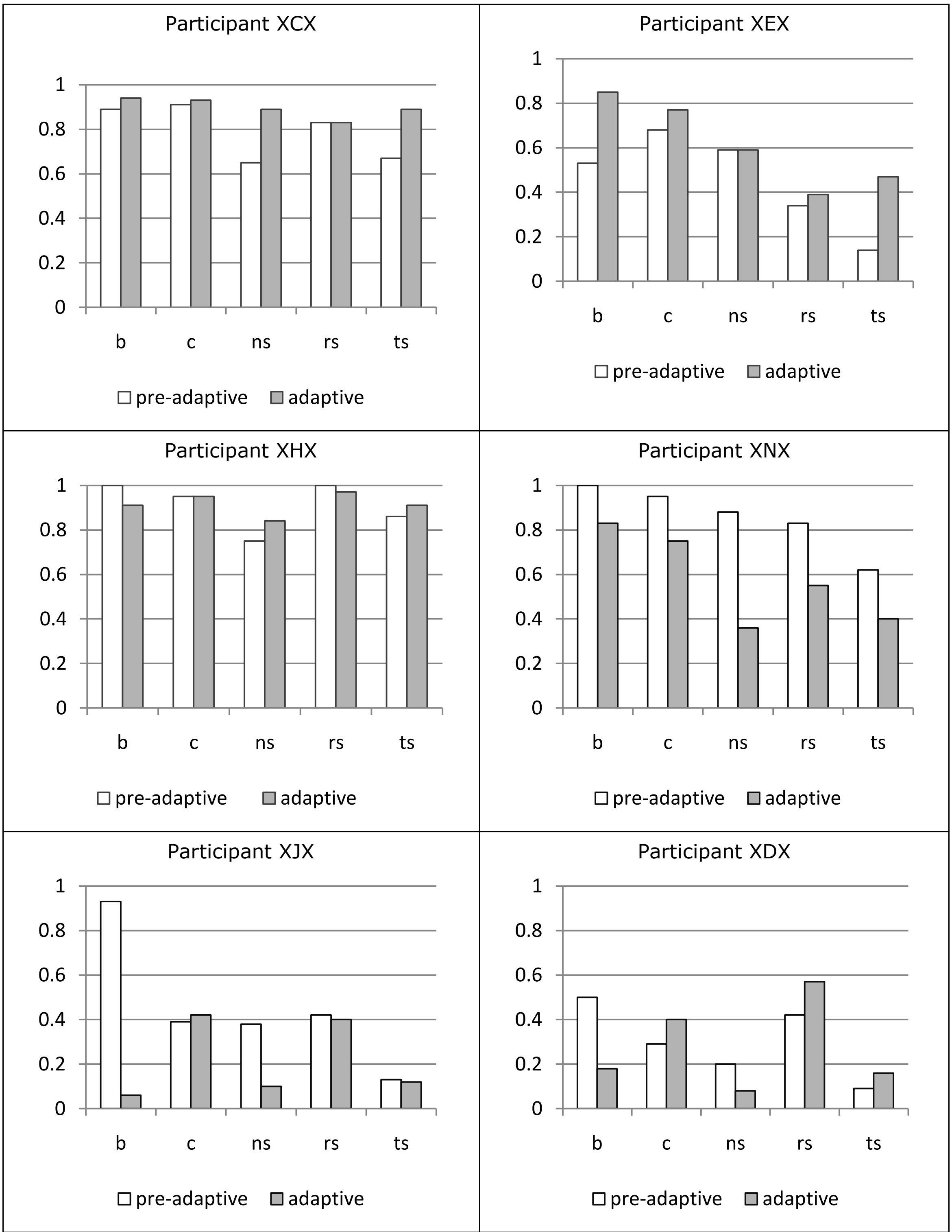
This appendix presents the results from trial 3 for the following measures:

- Results for measure M1 are summarised in chart form in *Appendix E Table 1: For each participant; the proportion of t-story instances from each proto-narrative category for which the correct answer was given at first attempt during the pre-adaptive and adaptive phases.*
- Results for measure M2 are summarised in chart form in *Appendix E Table 2: For each participant; the proportion of t story instances from each proto-narrative category for which the correct answer was given at first attempt during the pre-adaptive and post-adaptive phases*.
- Results for measure M3 are summarised in chart form in *Appendix E Table 3: For each participant, the numbers of correct and incorrect answers given during the adaptive phase in each proto-narrative category*.
- Results for measure M4 are summarised in chart form in *Appendix E Table 4: For each participant, the proportion of previously unseen t-stories from the proto-narrative categories which were the focus of adaptation*.
- Results for measure M5 are summarised in chart form in
- *Appendix E Table 5 A subjective measure of the engagement of each participant on each* visit.
- Results for measure M6 are not reproduced here as they are included in full in the main text.
- Results for measure M7 are presented in the following tables:
  - *Appendix E Table 6. Encoded log for participant XCX*.
  - *Appendix E Table 7. Encoded log for participant XEX*.
  - *Appendix E Table 8. Encoded log for participant XHX*.
  - *Appendix E Table 9. Encoded log for participant XNX.*

Measures M1 – M4 use data derived from the database logs using database tables and SQL queries shown in table: *Appendix E Table 10 Database tables and SQL queries used in the analysis of logged data.*

Measure 1

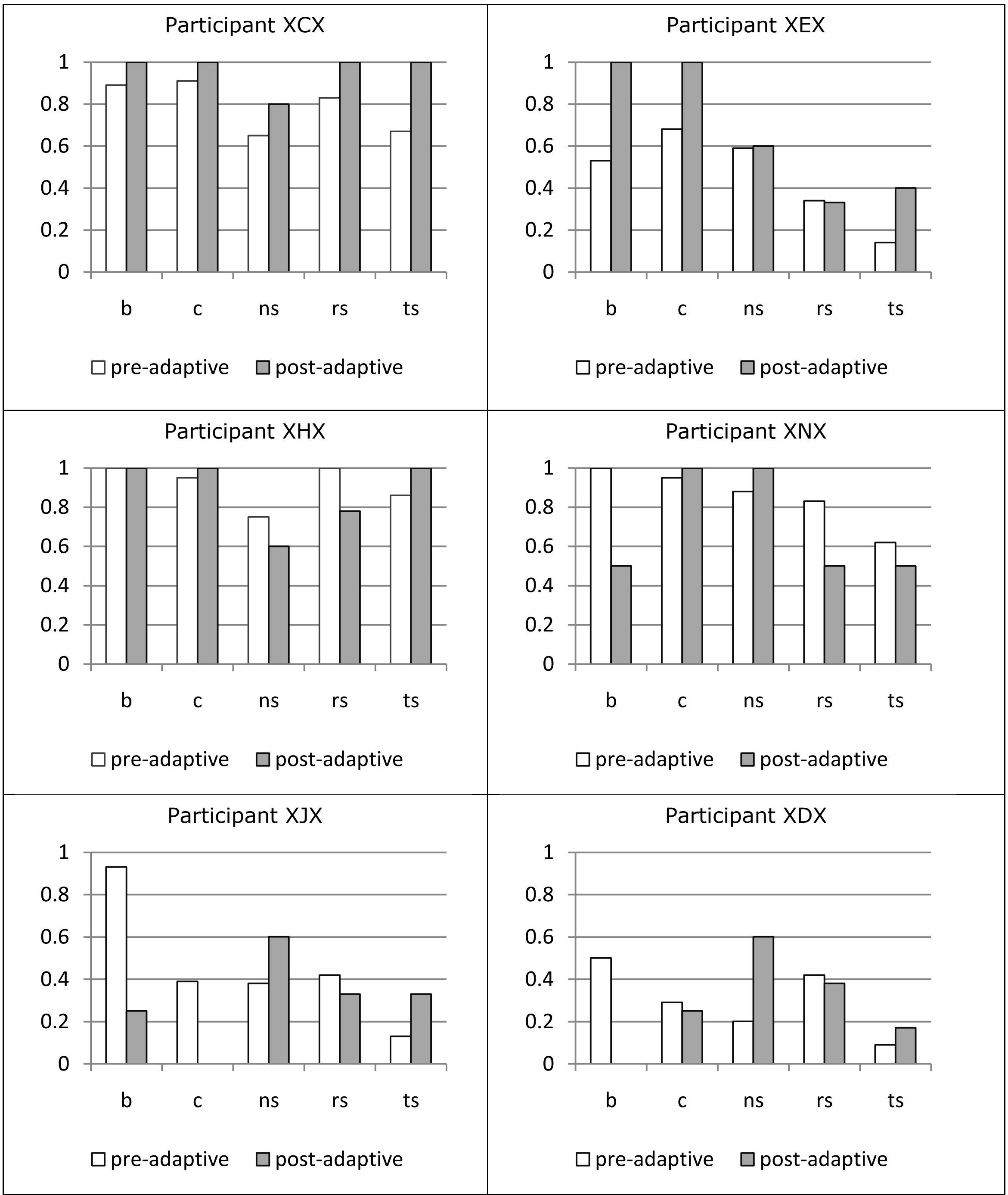
Appendix E Table 1: For each participant; the proportion of t-story instances from each proto-narrative category for which the correct answer was given at first attempt during the pre-adaptive and adaptive phases.



AXES for all charts:- X-axis:proto-narrative categories; Y-axis: **proportion** correct

Measure 2

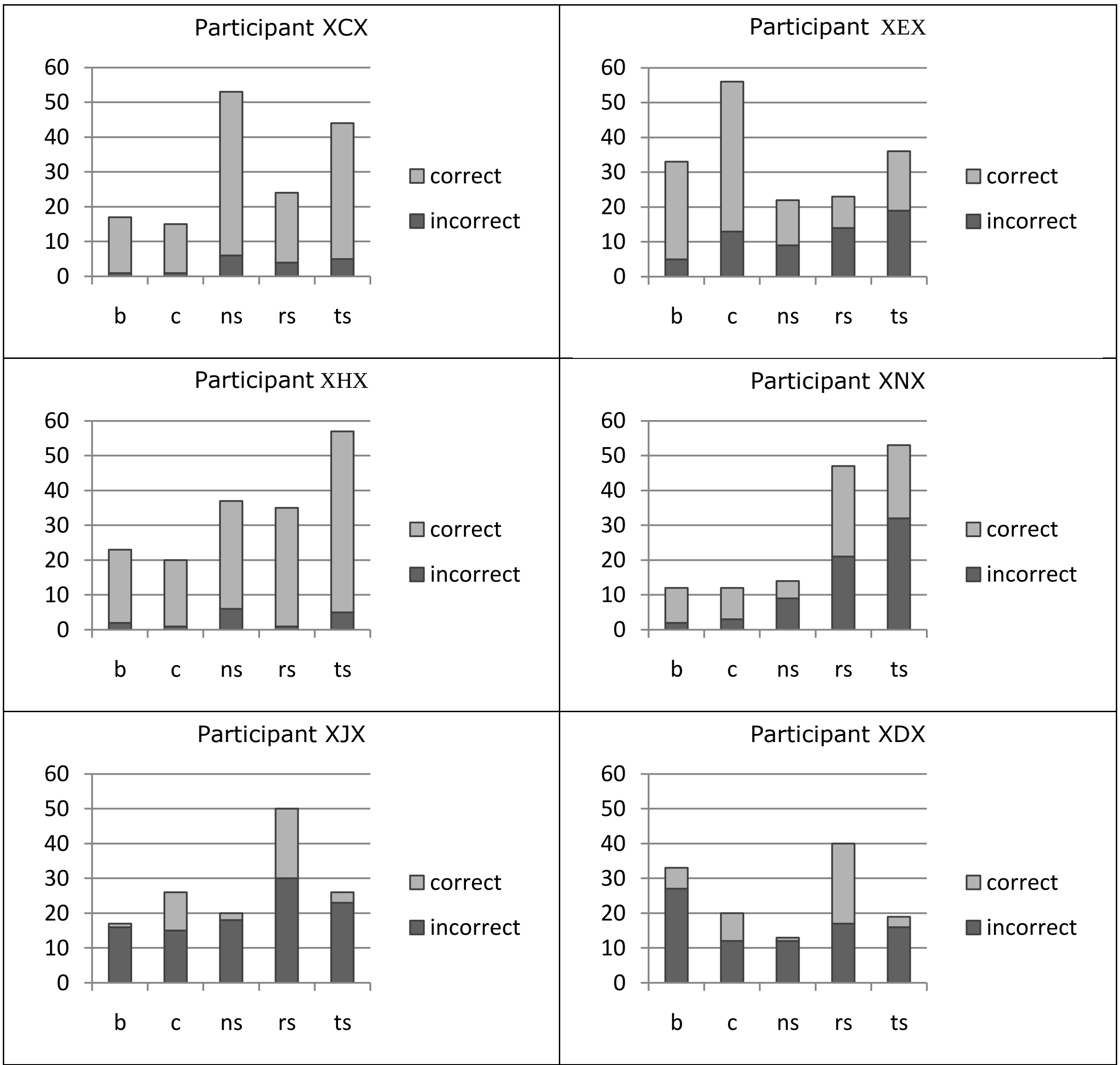
Appendix E Table 2: For each participant; the proportion of t story instances from each proto-narrative category for which the correct answer was given at first attempt during the pre-adaptive and post-adaptive phases



AXES for all charts:- X-axis:proto-narrative categories; Y-axis: **proportion** correct

Measure 3

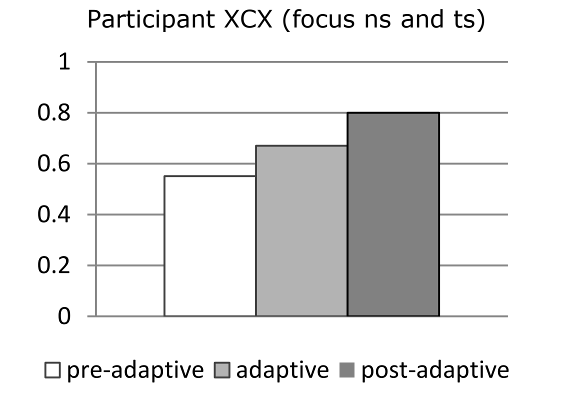
Appendix E Table 3: For each participant, the numbers of correct and incorrect answers given during the adaptive phase in each proto-narrative category

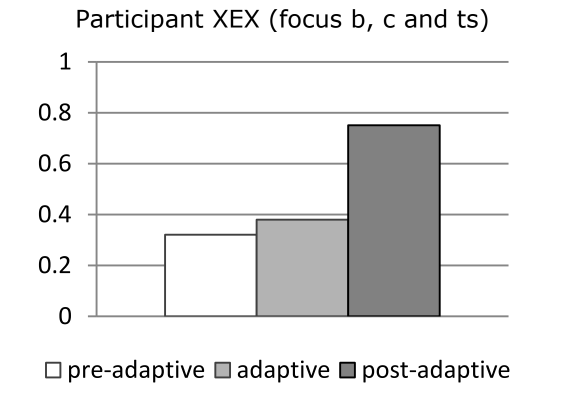


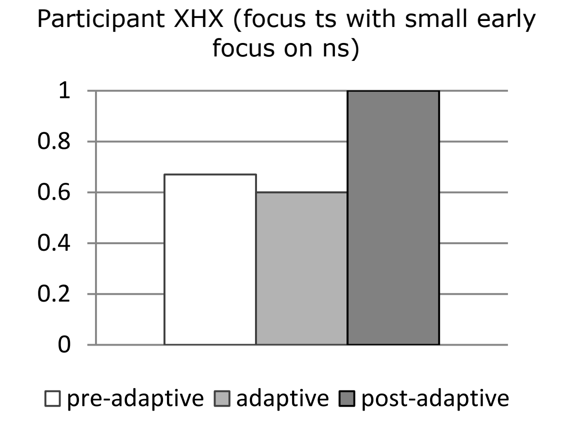
AXES for all charts:- X-axis: proto-narrative categories; Y-axis: **number** of correct and incorrect answers given

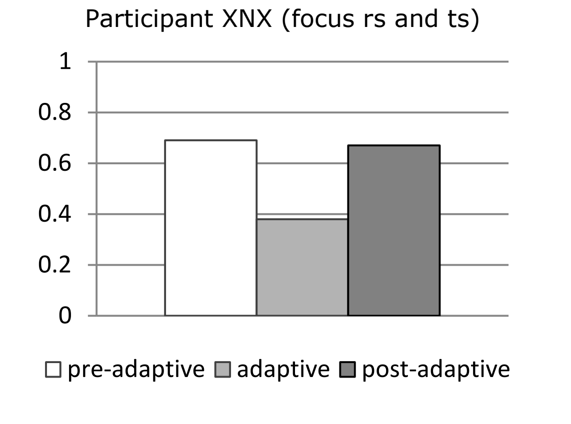
Measure 4

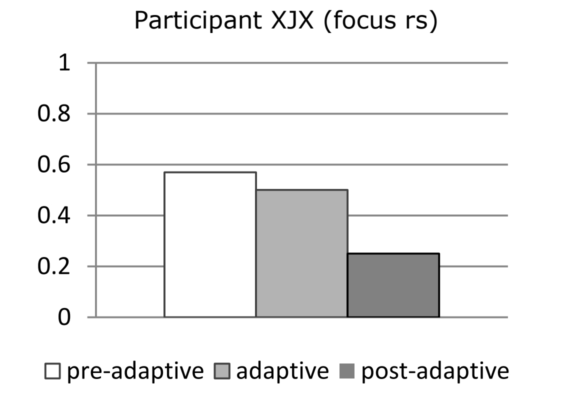
Appendix E Table 4: For each participant, the proportion of previously unseen t-stories from the proto-narrative categories which were the focus of adaptation for that participant

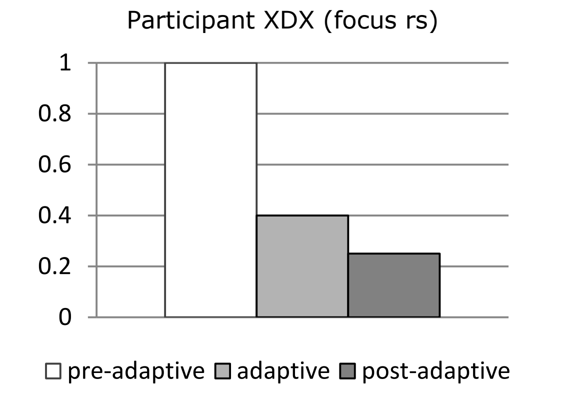








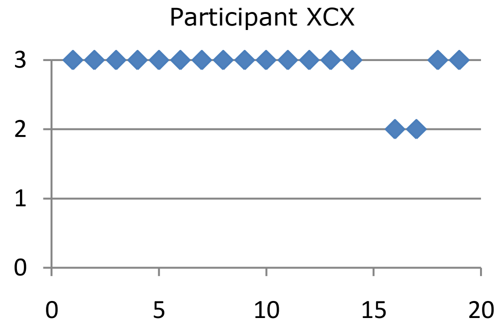




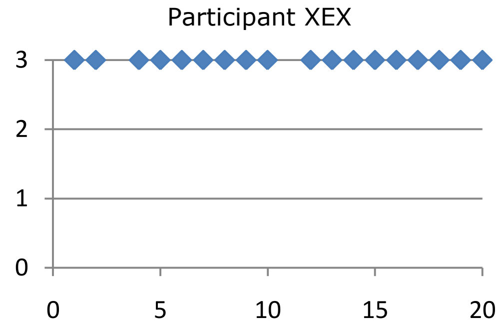
AXES for all charts:- X-axis: study phases; Y-axis: **proportion** of previously unseen t-stories correct at first attempt

Measure 5

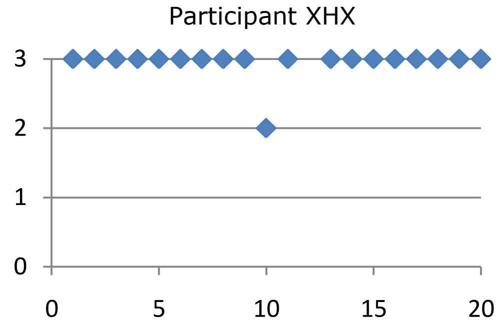
Appendix E Table 5 A subjective measure of the engagement of each participant on each visit



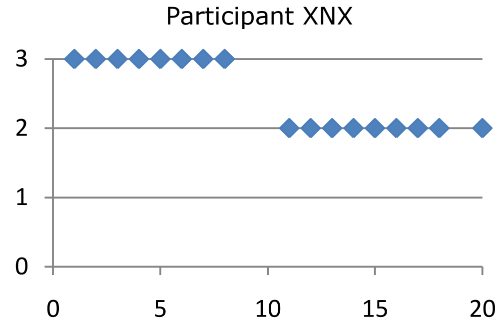
XCX was usually highly engaged, but a lower engagement was found in visits 16 and 17, this corresponds with all his school activities and is attributed, by the school, to external circumstances.



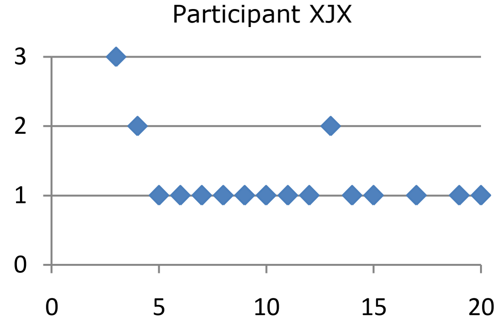
XEX showed continual high engagement.



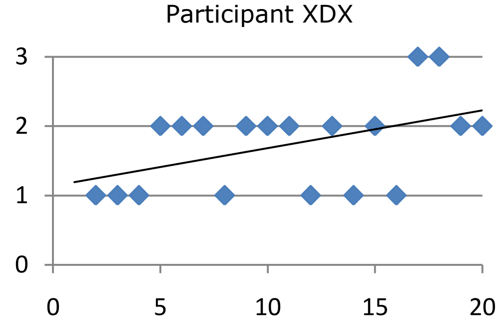
XHX showed distraction in visit 10 but is otherwise highly engaged. He did comment that the task was easy.



XNX became distracted later in the study, he was unsettled in all his schoolwork at that time. This was attributed, by the school, to external factors.



XJX showed less engagement as the study progressed, this is attributed, in part, to his desire to get to the final screen which he particularly likes.



XDX shows variable but generally increasing engagement. A trend line is added to further illustrate this

AXES for all charts:-
X-axis: visit shown by visit numbers;
Y-axis: subjective level of engagement with TouchStory where 3=highly engaged, 2=not fully engaged , going through the motions, 'not themselves', 1= distracted or needing to be coaxed, 0= present but interaction refused, missing values= the participant was not available (e.g. ill, at special classes off site, or on holiday)

Measure 6

Measure 6 which relates to particpants' reactions to the distractions put in place in session 6, and which is based on session notes and video sequences, is discussed in the main text and is intentionally not included in this appendix.

Measure 7

The following tables show the interaction details whenever a wrong answer was touched or moved. The encoding scheme, devised by the current author, is as follows:

- An option which is touched, moved to the empty panel and docked is represented by its option number, e.g. 1
- An option which is touched and moved, but not docked is represented by the option number in brackets, e.g. (1)
- An option which is touched, but not moved, or moved only minimally is shown in double brackets, e.g. ((1))
- An option correctly docked at first attempt is represented by a * e.g. (2)1* which means the participant moved but did not dock option 2, prior to docking the correct answer, n this case option 1.

Participant XCX

Appendix E Table 6. Encoded log for participant XCX. Columns are as follows: 't-story' gives the name of the t-story, 'type' gives the proto-narrative type, 'visit' gives the number of the visit, 'oc1' encodes the process of docking the first answer given by the participant, 'oc2' encodes the process of docking the second answer given, and 'oc3' encodes the process of docking the third answer given .

	t-story	type	visit	oc1	oc2	oc3
XCX	s3(1)	c	v1	0	1	
XCX	bluevase (1)	rs	v1	2	1	
XCX	bus(0)	rs	v1	(2)0*		
XCX	egg2a(2)	rs	v1	(1)2*		
XCX	o3(1)	rs	v1	0	1	
XCX	Balloons (2)	ts	v1	1	2	
XCX	eggcooking(2)	ts	v1	0	1	2
XCX	Sit(0)	ns	v2	1	2	0
XCX	bluevase (1)	rs	v2	(2)1*		
XCX	bus(0)	rs	v2	1	2	0
XCX	egg2a(2)	rs	v2	1	2	
XCX	Balloons (2)	ts	v2	1	0	2
XCX	sheep(1)	b	v3	2	1	
XCX	orange(3)	c	v3	1	2	
XCX	s3(1)	c	v3	(0)1*		
XCX	Sit(0)	ns	v3	1		

	t-story	type	visit	oc1	oc2	oc3
XCX	bus(0)	rs	v3	1	((2))((0))((1))0	
XCX	newballoon(0)	ts	v3	2	1	0
XCX	sheep(1)	b	v4	((1))2	1	
XCX	Sit(0)	ns	v4	1	2	0
XCX	Hair _c(0)	ns	v5	2	1	(0)(1)(2)0
XCX	Sit(0)	ns	v5	2	0	
XCX	bus(0)	rs	v5	((2))0*		
XCX	egg2a(2)	rs	v5	(1)2*		
XCX	o6a(1)	rs	v5	(2)1		
XCX	eggcooking(2)	ts	v5	((2))0	2	
XCX	kiwi2(0)	ts	v5	1	2	0
XCX	cross1(0)	c	v6	(1)0*		
XCX	Hair _c(0)	ns	v6	((2))0*		
XCX	Sit(0)	ns	v6	2	0	
XCX	bus(0)	rs	v6	(2)0*		
XCX	eggcooking(2)	ts	v6	(1)2*		
XCX	kiwi2(0)	ts	v6	2	1	0
XCX	b5(2)	b	v7	(1)2*		
XCX	Hair _c(0)	ns	v7	((2))0*		
XCX	newballoon(0)	ts	v7	(1)0*		
XCX	Hair _c(0)	ns	v8	((2))0*		
XCX	Sit(0)	ns	v8	2	1	0
XCX	kiwi2(0)	ts	v8	1	0	
XCX	eleslide(1)	c	v9	2	1	
XCX	cats(0)	ns	v9	2	0	
XCX	kiwi1(2)	rs	v9	(2)0	1	2
XCX	kiwi2(0)	ts	v9	2	0	
XCX	Sal(0)	c	v11	(2)0*		
XCX	dogs(0)	ns	v11	1	(2)0	
XCX	Sit(0)	ns	v11	2	1	0
XCX	kiwi1(2)	rs	v11	(0)(1)2*		
XCX	eggmeal(0)	ts	v11	1	0	
XCX	eggcooking(2)	ts	v14	0	2	
XCX	FB(2)	b	v16	0	1	2
XCX	Ted(0)	ns	v16	1	0	
XCX	doh(2)	ts	v16	1	2	
XCX	Ted(0)	ns	v17	1	2	0
XCX	NFB(1)	rs	v17	2	1	
XCX	Q(0)	rs	v17	1	0	
XCX	B(0)	ts	v17	(1)0*		
XCX	Hair _c(0)	ns	v18	(0)((1))0*		
XCX	Q(0)	rs	v18	1	0	

	t-story	type	visit	oc1	oc2	oc3
XCX	b6(0)	b	v20	(2)0*		
XCX	bvn(1)	ns	v20	2	0	1
XCX	bus2(2)	rs	v20	((0))2*		

Participant XEX

Appendix E Table 7. Encoded log for participant XEX. . Columns are as follows: 't-story' gives the name of the t-story, 'type' gives the proto-narrative type, 'visit' gives the number of the visit, 'oc1' encodes the process of docking the first answer given by the participant, 'oc2' encodes the process of docking the second answer given, and 'oc3' encodes the process of docking the third answer given .

	t-story	type	visit	oc1	oc2	oc3
XEX	s3(1)	c	v1	0		
XEX	Hairy(1)	ns	v1	(0)1*		
XEX	egg1a(2)	rs	v1	1		
XEX	egg2a(2)	rs	v1	1		
XEX	o3(1)	rs	v1	0		
XEX	Balloons (2)	ts	v1	0		
XEX	eggcooking(2)	ts	v1	(1)2*		
XEX	tick(1)	ts	v1	0	1	
XEX	b3(1)	b	v1	0		
XEX	eleslide(1)	c	v10	2	1	
XEX	s1(0)	c	v10	(1)0*		
XEX	cats(0)	ns	v10	1	(2)0	
XEX	egg3a(2)	ts	v10	2	1	
XEX	opeel(0)	ts	v10	2	1	0
XEX	cats(0)	ns	v11	2	0	
XEX	kiwi1(2)	rs	v11	1	2	
XEX	o6(1)	rs	v11	2	1	
XEX	eggmeal(0)	ts	v11	2	0	
XEX	opeel(0)	ts	v11	2	(1)0	
XEX	eleslide(1)	c	v12	0	2	1
XEX	cats(0)	ns	v12	2		
XEX	kiwi1(2)	rs	v12	1	2	
XEX	o6(1)	rs	v12	2	1	
XEX	egg3a(2)	ts	v12	((2))(0)2	1	
XEX	eggmeal(0)	ts	v12	2	(1)(2)(1)(0)(1)0	
XEX	opeel(0)	ts	v12	2	(1)0	
XEX	eleslide(1)	c	v13	2	1	
XEX	juice	rs	v13	2	1	0
XEX	kiwi1(2)	rs	v13	1	2	

	t-story	type	visit	oc1	oc2	oc3
XEX	o6(1)	rs	v13	2	1	
XEX	egg3a(2)	ts	v13	2	1	
XEX	eggmeal(0)	ts	v13	1	(2)0	
XEX	flower(0)	ts	v13	1	(2)0	
XEX	opeel(0)	ts	v13	1	0	
XEX	FB(2)	b	v15	1	2	
XEX	Tedstory(1)	c	v15	2	1	
XEX	cats(0)	ns	v15	2	0	
XEX	Ted(0)	ns	v15	1	(2)0	
XEX	NFB(1)	rs	v15	0	1	
XEX	eggmeal(0)	ts	v15	2	0	
XEX	flower(0)	ts	v15	1	0	
XEX	opeel(0)	ts	v15	((2))((0))(1)0*		
XEX	FB(2)	b	v16	0	1	2
XEX	eleslide(1)	c	v16	(2)1*		
XEX	Tedstory(1)	c	v16	2	1	
XEX	NFB(1)	rs	v16	0	1	
XEX	doh(2)	ts	v16	0	(1)(2)(1)2	
XEX	newballoon(0)	ts	v16	(1)2	0	
XEX	C(1)	c	v17	(2)0	1	
XEX	eleslide(1)	c	v17	((1))(2)1*		
XEX	Tedstory(1)	c	v17	2	1	
XEX	set(1)	ns	v17	2	1	
XEX	Ted(0)	ns	v17	2	1	0
XEX	NFB(1)	rs	v17	2	1	
XEX	Q(0)	rs	v17	1	0	
XEX	B(0)	ts	v17	(0)(1)2	0	
XEX	BB(2)	b	v18	(2)((0))2*		
XEX	C(1)	c	v18	2	1	
XEX	eleslide(1)	c	v18	0	1	
XEX	Tedstory(1)	c	v18	2	1	
XEX	set(1)	ns	v18	(0)1*		
XEX	NFB(1)	rs	v18	2	1	
XEX	Q(0)	rs	v18	2	1	
XEX	Sit(0)	ns	v19	(0)(2)0*		
XEX	egg1a(2)	rs	v19	1	0	2
XEX	o3(1)	rs	v19	0	1	
XEX	eggcooking(2)	ts	v19	1	2	
XEX	tick(1)	ts	v19	2	1	
XEX	b3(1)	b	v2	0	1	
XEX	Hairy(1)	ns	v2	0	2	1
XEX	bus(0)	rs	v2	1	2	0

	t-story	type	visit	oc1	oc2	oc3
XEX	egg1a(2)	rs	v2	1	2	
XEX	egg2a(2)	rs	v2	1	2	
XEX	Balloons (2)	ts	v2	1	2	
XEX	eggcooking(2)	ts	v2	1	2	
XEX	tick(1)	ts	v2	2	1	
XEX	bvn(1)	ns	v20	2	(0)1	
XEX	Hair(2)	ns	v20	1	(0)2	
XEX	bus2(2)	rs	v20	1	2	
XEX	egg2(2)	rs	v20	0	2	
XEX	o2a(2)	rs	v20	1	0	2
XEX	o5(1)	rs	v20	0	1	
XEX	egg3(2)	ts	v20	1	2	0
XEX	b3(1)	b	v3	0	2	1
XEX	sheep(1)	b	v3	2	1	
XEX	starB(1)	b	v3	2	1	
XEX	orange(2)	c	v3	1	0	2
XEX	bluevase (1)	rs	v3	0	1	
XEX	bus(0)	rs	v3	1	(2)0	
XEX	egg1a(2)	rs	v3	1	(0)2	
XEX	egg2a(2)	rs	v3	1	(0)2	
XEX	eggcooking(2)	ts	v3	1	2	
XEX	newballoon(0)	ts	v3	1	(2)0	
XEX	tick(1)	ts	v3	2	1	
XEX	b3(1)	b	v4	0	1	
XEX	starB(1)	b	v4	2	(0)1	
XEX	orange(2)	c	v4	(1)2*		
XEX	s3(1)	c	v4	0	2	1
XEX	Sit(0)	ns	v4	1	(0)(2)0	
XEX	bluevase (1)	rs	v4	0	1	
XEX	bus(0)	rs	v4	1	2	0
XEX	egg1a(2)	rs	v4	1	2	
XEX	egg2a(2)	rs	v4	1	((2))(0)2	
XEX	eggcooking(2)	ts	v4	1	(0)2	
XEX	newballoon(0)	ts	v4	1	2	0
XEX	starB(1)	b	v5	0	1	
XEX	c1(1)	c	v5	0	1	
XEX	cross1(0)	c	v5	1	0	
XEX	Hair _c(0)	ns	v5	1	((2))0	
XEX	Sit(0)	ns	v5	1	2	0
XEX	bus(0)	rs	v5	1	2	0
XEX	egg2a(2)	rs	v5	1	2	
XEX	eggcooking(2)	ts	v5	1	(0)2	

	t-story	type	visit	oc1	oc2	oc3
XEX	kiwi2(0)	ts	v5	1	2	0
XEX	newballoon(0)	ts	v5	1	0	
XEX	c1(1)	c	v6	0	1	
XEX	Hair _c(0)	ns	v6	2	1	0
XEX	bus(0)	rs	v6	1	2	0
XEX	egg2a(2)	rs	v6	1	2	
XEX	kiwi2(0)	ts	v6	1	(2)0	
XEX	newballoon(0)	ts	v6	1	(2)0	
XEX	b5(2)	b	v7	0	2	
XEX	cross1(0)	c	v7	1	0	
XEX	Hair _c(0)	ns	v7	2	0	
XEX	Rain(2)	ns	v7	1	2	
XEX	bus(0)	rs	v7	1	2	0
XEX	egg3a(2)	ts	v7	0	1	
XEX	kiwi2(0)	ts	v7	2	((1))0	
XEX	newballoon(0)	ts	v7	1	2	0
XEX	b5(2)	b	v8	0	2	
XEX	sheep(1)	b	v8	2	1	
XEX	Hair _c(0)	ns	v8	2		
XEX	bus(0)	rs	v8	1	2	0
XEX	b5(2)	b	v9	1	2	
XEX	eleslide(1)	c	v9	0	1	
XEX	cats(0)	ns	v9	1	(2)0	
XEX	opeel(0)	ts	v9	2	1	0

Participant XHX

Appendix E Table 8. Encoded log for participant XHX. . Columns are as follows: 't-story' gives the name of the t-story, 'type' gives the proto-narrative type, 'visit' gives the number of the visit, 'oc1' encodes the process of docking the first answer given by the participant, 'oc2' encodes the process of docking the second answer given, and 'oc3' encodes the process of docking the third answer given .

	t-story	type	visit	oc1	oc2	oc3
XHX	s3(1)	c	v1	0	1	
XHX	Balloons (2)	ts	v1	0		
XHX	b2(2)	b	v2	(0)2*		
XHX	Sit(0)	ns	v3	1		
XHX	Sit(0)	ns	v4	((2))((2))1		
XHX	sheep(1)	b	v5	(2)1*		
XHX	Sit(0)	ns	v5	1		

XHX	kiwi2(0)	ts	v5	1		
XHX	Sit(0)	ns	v6	1		
XHX	kiwi2(0)	ts	v7	1	0	
XHX	Sit(0)	ns	v8	1		
XHX	bus(0)	rs	v8	(1)0*		
XHX	kiwi1(2)	rs	v9	1	2	
XHX	b7(2)	b	v11	0		
XHX	Sit(0)	ns	v11	1		
XHX	opeel(0)	ts	v12	1	0	
XHX	b7(2)	b	v13	(0)2*		
XHX	egg3a(2)	ts	v13	((2))1		
XHX	flower(0)	ts	v13	1		
XHX	flower(0)	ts	v14	(1)0*		
XHX	Tedstory(1)	c	v15	2	1	
XHX	Ted(0)	ns	v15	1	2	0
XHX	doh(2)	ts	v15	(2)1	0	
XHX	flower(0)	ts	v15	(1)0*		
XHX	FB(2)	b	v16	0	2	
XHX	Ted(0)	ns	v16	1	0	
XHX	doh(2)	ts	v16	1	2	
XHX	set(1)	ns	v17	2	1	
XHX	doh(2)	ts	v17	1	2	
XHX	Sit(0)	ns	v19	1	0	
XHX	bus(0)	rs	v19	(1)0*		
XHX	egg2a(2)	rs	v19	1		
XHX	bvn(1)	ns	v20	2	1	
XHX	egg2a(2)	rs	v20	(0)2*		
XHX	o2a(2)	rs	v20	1	2	

Participant XNX

Appendix E Table 9. Encoded log for participant XNX. . Columns are as follows: 't-story' gives the name of the t-story, 'type' gives the proto-narrative type, 'visit' gives the number of the visit, 'oc1' encodes the process of docking the first answer given by the participant, 'oc2' encodes the process of docking the second answer given, and 'oc3' encodes the process of docking the third answer given .

	t-story	type	visit	oc1	0c2	oc3
XNX	s3(1)	c	v1	(1)0	1	
XNX	Hairy(1)	ns	v1	((2))1*		
XNX	bluevase(0)	rs	v1	(2)1		
XNX	egg2a(2)	rs	v1	0		
XNX	Balloons (2)	ts	v1	1		
XNX	bluevase(0)	rs	v2	(0)1		
XNX	bus(0)	rs	v2	1	0	
XNX	Balloons (2)	ts	v2	0		
XNX	sheep(1)	b	v3	(0)(2)1*		
XNX	egg2a(2)	rs	v3	(0)2*		
XNX	newballoon(0)	ts	v3	2		
XNX	sheep(1)	b	v4	((0))1*		
XNX	bus(0)	rs	v4	1	0	
XNX	newballoon(0)	ts	v4	2		
XNX	Sit(0)	ns	v5	1	2	0
XNX	kiwi2(0)	ts	v5	1	2	0
XNX	newballoon(0)	ts	v5	2	0	
XNX	Sit(0)	ns	v6	1	0	
XNX	bus(0)	rs	v6	2	1	0
XNX	kiwi2(0)	ts	v6	1	2	0
XNX	bus(0)	rs	v7	1	2	0
XNX	kiwi2(0)	ts	v7	1	(2)0	
XNX	sal(0)	c	v12	(1)0*		
XNX	dogs(0)	ns	v12	1	2	0
XNX	kiwi1(2)	rs	v12	1	2	0
XNX	egg3a(2)	ts	v12	0	1	
XNX	eggcooking(2)	ts	v12	0	2	
XNX	eggmeal(0)	ts	v12	2	1	0
XNX	opeel(0)	ts	v12	((1))(2)((1))0		
XNX	cats(0)	ns	v13	1	2	0
XNX	dogs(0)	ns	v13	1	2	0
XNX	bus(0)	rs	v13	1	(2)0	
XNX	juice(0)	rs	v13	1	2	0
XNX	kiwi1(2)	rs	v13	1	2	
XNX	balloons (2)	ts	v13	((1))2*		

	t-story	type	visit	oc1	0c2	oc3
XNX	eggcooking(2)	ts	v13	((1))0	1	2
XNX	eggmeal(0)	ts	v13	1	2	0
XNX	flower(0)	ts	v13	1	(2)0	
XNX	kiwi2(0)	ts	v13	1	2	0
XNX	opeel(0)	ts	v13	2	0	
XNX	dogs(0)	ns	v14	1	2	0
XNX	bus(0)	rs	v14	1	2	0
XNX	juice(0)	rs	v14	2	1	0
XNX	kiwi1(2)	rs	v14	1	2	
XNX	o6(1)	rs	v14	2	1	
XNX	eggcooking(2)	ts	v14	(1)0	1	2
XNX	eggmeal(0)	ts	v14	2	0	
XNX	flower(0)	ts	v14	2	0	
XNX	kiwi2(0)	ts	v14	1	2	0
XNX	opeel(0)	ts	v14	2	1	0
XNX	Tedstory(1)	c	v15	2	1	
XNX	Ted(0)	ns	v15	2	1	0
XNX	juice(0)	rs	v15	(2)0*		
XNX	NFB(1)	rs	v15	2	1	
XNX	o6(1)	rs	v15	2		
XNX	eggmeal(0)	ts	v15	2	1	0
XNX	flower(0)	ts	v15	2	1	0
XNX	kiwi2(0)	ts	v15	2		
XNX	opeel(0)	ts	v15	2	1	0
XNX	Tedstory(1)	c	v16	2	1	
XNX	Ted(0)	ns	v16	1	2	0
XNX	bus(0)	rs	v16	2	1	
XNX	eggmeal(0)	ts	v16	1	(2)0	
XNX	tick(1)	ts	v16	2	1	
XNX	BB(2)	b	v17	1	2	
XNX	C(1)	c	v17	2	1	
XNX	set(1)	ns	v17	2	1	
XNX	bluevase(0)	rs	v17	0	1	
XNX	bus(0)	rs	v17	1	2	0
XNX	juice(0)	rs	v17	((1))((2))0*		
XNX	o6(1)	rs	v17	2		
XNX	Q(0)	rs	v17	1	(2)0	
XNX	doh(2)	ts	v17	1	2	
XNX	eggmeal(0)	ts	v17	1	2	0
XNX	flower(0)	ts	v17	2	1	0
XNX	newballoon(0)	ts	v17	2	(1)0	
XNX	BB(2)	b	v18	1	2	

	t-story	type	visit	oc1	0c2	oc3
XNX	set(1)	ns	v18	2	1	
XNX	bus(0)	rs	v18	1	(2)0	
XNX	juice(0)	rs	v18	((2))0*		
XNX	NFB(1)	rs	v18	2	1	
XNX	o6(1)	rs	v18	2	1	
XNX	Q(0)	rs	v18	1	(2)0	
XNX	B(0)	ts	v18	((1))0*		
XNX	doh(2)	ts	v18	1	0	2
XNX	eggmeal(0)	ts	v18	(1)0*		
XNX	flower(0)	ts	v18	(2)1	0	
XNX	b4(0)	b	v20	(2)(1)0*		
XNX	bus2	rs	v20	1	2	
XNX	egg2(2)	rs	v20	((0))1	2	
XNX	egg3(2)	ts	v20	(2)0		

Database tables and SQL queries used in the analysis of logged data

Appendix E Table 10 Database tables and SQL queries used in the analysis of logged data.

DB object	Type	Role
Child child(name, visit, logged, story, isCorrect)	Table	A base table. It is the relation that TouchStory logs to.
Stories	Table	the stories catalogue: a TouchStory base table
Map	Table	a stored function mapping Boolean values to integers 1/0 for ease of processing
Map2	Table	encodes a number of stored functions, such as mapping from visit identifier to the week in which that visit was held, facilitating analysis by week (i.e. per adaptive cycle) rather than by visit.
log2 populated from INSERT INTO log2 (name, visit, logged, story, stype, correct) SELECT child.name, child.visit, child.logged, child.story, Stories.stype, map.correct FROM (child INNER JOIN map ON child.isCorrect=map.isCorrect) INNER JOIN Stories ON child.story=Stories.storyname ORDER BY child.name, child.visit;	Table	An intermediate table common to several analysis queries As Child except • stype is included – stype indicates the proto-narrative category which the t-story is from, • the Boolean outcome is mapped to 1/0 for ease of processing
Query14 SELECT log2.* INTO log2tidy FROM log2 WHERE name Not In ("child10","child12");	Query / view	View of log2 restricted to participants' data only. Note "child10" and "child12" were identifiers used by the moderating panel.
Maplog SELECT log2tidy.*, map2.week, map2.odd, map2.set, map2.adaptive, map2.focus FROM map2 INNER JOIN log2tidy ON map2.visit = log2tidy.visit;	Query / view	Extends log2tidy with additional data: • the *week* of the study • whether the visit was an odd or even visit • the visual complexity measure of the t-story • the phase of study with respect to adaptation whether the visit is a focus points (such as visit 19 and 20)
Dstorycount SELECT log2tidy.story FROM log2tidy GROUP BY story;	Query	A list of t-stories answered by participants during the trial (and so also the numberof t-stories used)

DB object	**Type**	**Role**
Log2tidy_Crosstab TRANSFORM Count(log2tidy.logged) AS CountOflogged SELECT log2tidy.name, Count(log2tidy.logged) AS [Total Of logged] FROM log2tidy GROUP BY log2tidy.name PIVOT log2tidy.visit;	Xtab query	For each child; the *number* of t-stories answered each visit and in total throughout the study.
Correctpcv TRANSFORM Sum(correct) AS countcorrect SELECT name FROM log2tidy GROUP BY name PIVOT visit;	Xtab query	For each child; the *number* of t-stories *answered correctly* in total at each visit.
Scountpct TRANSFORM Count(story) AS CountOfstory SELECT name, Count(story) AS [Total Of story] FROM log2tidy GROUP BY name PIVOT stype;	Xtab query	For each child; the total number of t-story instances of each stype answered during the study
Answeredpctv TRANSFORM Count(logged) AS CountOflogged SELECT name, stype, Count(logged) AS [Total Of logged] FROM log2tidy GROUP BY name, stype PIVOT visit;	Xtab query	For each child, stype; the *number* of t-stories answered at each visit and in total throughout study Used n the preparation of Measure M3.
Adaptive_focus	Table	For each child, stype; whether the stype was the focus of positive adaptation for that child. Used in the preparative of results for measure M4.
Maplog_Crosstab11 TRANSFORM Round(Avg(maplog.[correct]),2) AS AvgOfcorrect SELECT maplog.name, maplog.stype FROM maplog GROUP BY maplog.name, maplog.stype PIVOT maplog.adaptive;	Xtab query	For each adaptive phase, child, stype; the number of t-stories answered *correctly* as a *proportion* of the number answered Used for measures M1 and M2.

DB object	Type	Role
Query21 SELECT log2tidy.name, log2tidy.story, count(correct) as answered, sum (correct) as timesCorrect FROM log2tidy group by log2tidy.name, log2tidy.story having count(correct) > sum (correct);	query	For each child, for each t-story which the child got wrong at least once; the number of times it was answered and the number of times it was answered correctly. Used in consideration of measure M7
whotypeweek TRANSFORM Count(maplog.[correct]) AS CountOfcorrect SELECT maplog.[name], maplog.[stype], Count(maplog.[correct]) AS [Total Of correct] FROM maplog WHERE week<10 GROUP BY maplog.[name], maplog.[stype] PIVOT maplog.[week];	Xtab query	For each child, stype, week; the number of t-stories answered (note it is only counting answers, it is not counting correct answers --basically it is counting relevant rows) Used in the preparation of the charts in Table 8.6 which shows the impact of adaptation on the numbers of t-stories seen by each participant in each proto-narrative category
maplogCrosstab12 TRANSFORM Count(maplog.[correct]) AS CountOfcorrect SELECT maplog.[name], maplog.[stype] FROM maplog GROUP BY maplog.[name], maplog.[stype] PIVOT maplog.[adaptive];	Xtab query	For each phase, child, stype; the number of t-stories completed Used in the preparation of Table 8.6
maplog adaptive SELECT maplog.[name], maplog.[stype], Count(maplog.[correct]) AS Total, Sum(maplog.[correct]) AS Correct FROM maplog WHERE visit>7 And visit<19 GROUP BY maplog.[name], maplog.[stype];	Query	Restricted to the adaptive phase only: for each child, stype; the number of the number of t-stories answered and the number answered correctly. Used in the preparation of Table 8.6
Seen SELECT log2tidy.name, count (*) AS tstoriesSeen, sum (correct) AS totalcorrect FROM log2tidy GROUP BY name;	Query	For each child; the number of t-stories completed and number completed correctly during the whole study. Used in the preparation of Table 8.6

DB object	Type	Role
Query17 SELECT log2tidy.story, min(visit) AS firstUsed FROM log2tidy GROUP BY story;	Query	For each t-story the visit it was first used.
maplogfirstused SELECT log2tidy.*, map2.week, map2.adaptive, [adaptive focus].focus, Query17.firstUsed FROM ((map2 INNER JOIN log2tidy ON map2.visit=log2tidy.visit) INNER JOIN Query17 ON log2tidy.story=Query17.story) INNER JOIN [adaptive focus] ON (log2tidy.name=[adaptive focus].childsName) AND (log2tidy.stype=[adaptive focus].stype) WHERE map2.visit=Query17.firstused;	Query	For each child, visit, t-story; Gives full details of each completed t-story, restricted to those t-stories being shown for the first time. Used in the preparation of results for measure M4.

APPENDIX F: TOUCHSTORY

TouchStory experimenter's user guide

Conducting a session

These instructions assume that the TouchStory session has been prepared and that you now want to conduct the session. If it the session has not been prepared then please see the section called 'Setting up a visit' below.

To start the session

- Double click on the 'Shortcut to TS.bat' icon on the desktop
- Click on the participant's name

Troubleshooting

- For the first session of a day you might find the game does not start when you click on the participant's name: in this case close the TouchStory window and restart as above.

During the session

- The NEXT button is used to move to the next t-story
- The AGAIN button is sometimes useful, it resets the options in the current t-story to their start positions
- By design there is no 'back' button

At the end of the session

- Close the final screen using the 'close' button
- Close the game screen using the 'close' button

After the session

- The text logs for each session can be found in the `TouchStory\myclasses` directory and have names such as `TS101312.dat`. You may rename these files.
- The database log can be found in `TouchStory\Myprogs>storydb.mdb>table:child`

Setting up a visit

- The visit number is currently hard-coded in `CurrentChild.java`. To prepare for a visit open `CurrentChild.java` and edit the `visit` variable to the number of the planned visit, save and recompile. For example, to prepare for visit 3, change the value of `visit` to 3.

Then set up a session for each participant. This can be done either by hand or by running the program Populate.

- By hand: for a participant named child1, open `storydb.mdb` and then open the table called `child1`, delete any existing rows and enter the list of t-stories the participant is to see.
- Using Populate: to set up visit v3, at the DOS command type as follows;
  `>java Populate 3`

Applying adaptive formula prior to a visit

Adaptation is a separate process allowing the experimenter to choose the number of visits in each adaptive cycle. For example, adaptation may be applied prior to every second visit.

- To apply an adaptation for each participant in the trial based on his or her profile up to, say, visit `v9`, at the DOS prompt type as follows:
  `> java TSAdapter2 – v9`
- Then run `Populate` as before.

Setting up a trial

- Participant names are hard coded into both `FirstScreen.java` and `Populate.java`, these should be edited, saved and recompiled.
- Set up a table for each participant in the StoryDB database with one attribute called `name, e.g. Child1(name).`
- Populate the `Schedule` table with the details of the t-stories you want to use on each visit. This can be done at the beginning of the trial or rows can be added on a per visit basis. The latter has the advantage that you not have to cater for situations which are in fact never reached.

Installing TouchStory

TouchStory was developed under WindowsXE, it has not been tested on any other platform. It requires the java JDK and RTE, and Microsoft Access.

- TouchStory is in two folders `Myprogs` and `myclasses,` put these in some directory of your choice, e.g. `yourdir`.
- Create a shortcut to `TS.bat` (to be found in `myclasses`) and put it on the desktop
- Notes:
  - The database must be in `Myprogs`
  - The class files and image files must be in `myclasses`

Adding new t-stories

New t-stories may be added subject to the following constraints
- there are no more than 5 panels
- there are three options
- images are about 200 x 132 pixels

Full details are not given here.

TouchStory programs

The TouchStory suite of programs comprises three programs

- TouchStory // to play the TouchStory game
- Populate // to set up the t-stories to be seen
- Adapt // to apply the adaptive function

Class TouchStory

TouchStory.java

```
// main program
//calls MyOut, FirstScreen, Dragger2

import java.awt.*;
import javax.swing.*;
import java.awt.event.*;
import java.util.Date;

public class TouchStory extends JPanel implements ActionListener{

  Timer threesecs = new Timer(3000, this);
  JFrame frame = new JFrame ("TouchStory Dragger");
  MyOut out = new MyOut();
  Kbd kbd = new Kbd();

  public void actionPerformed (ActionEvent e){
    JComponent newContentPane = new Dragger2(out);
    newContentPane.setOpaque(true);
    frame.setContentPane(newContentPane);

    frame.pack();
    frame.setVisible(true);
  }
  public TouchStory(){
    Date d = new Date();
    out.makeOut("TS"+ d.getHours()+d.getMinutes()+d.getSeconds()+".dat");
    frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);

    frame.addWindowListener(new WindowAdapter(){
        public void windowClosed (WindowEvent e){
          out.closeOut();
          System.exit(0);}});

    ///////////////////////////////////////
    JComponent firstContentPane = new FirstScreen(out);
    firstContentPane.setOpaque(true);
    frame.setContentPane(firstContentPane);

    frame.pack();
    frame.setVisible(true);

    threesecs.setRepeats(false);
    threesecs.start();
```

TouchStory.java

```
  }//end TouchStory constructor
  public static void main(String[] args) {
      TouchStory ts = new TouchStory();
  }// end main
} //end of TouchStory
```

Class MyOut

MyOut.java

```
// for creating, adding to, and closing logfiles

import java.io.*

public class MyOut {
  private PrintWriter outFile;
  public void makeOut (String s){
    try {
      FileWriter fw = new FileWriter (s);
      outFile = new PrintWriter(fw);
    }
    catch (Exception e){
      System.out.println("stuck");
    }
  }
  public void print (String s){
    outFile.print(s);
  }
  public void println (String s){
    outFile.println(s);
  }
  public void closeOut() {
    outFile.close();
    System.out.println("output file created");
  }
}
```

Class FirstScreen

FirstScreen.java

```
// the initial or 'login' screen
// calls CurrentChild
// participant’s names have been made anonymous

import java.awt.*;
import javax.swing.*;
import java.awt.event.*;

public class FirstScreen extends JPanel{

  private JLabel touchstory;
  private JPanel namesPanel = new JPanel(new GridLayout(3,4));
  private JButton[] namesButtons = new JButton[12];
```

```
private String[] names = {"ch1","ch2","ch3","ch4","ch5",
            "ch6","ch7","ch8", "ch9", "ch10", "ch11","ch12"};
private NameListener nameListener = new NameListener();

private MyOut FSout;

public FirstScreen(MyOut out){
//lays out the introductory screen and listens for child login

  FSout = out;
   //FSout.println("in first screen");//testing
  this.setPreferredSize (new Dimension (1018, 750));
  this.setLayout ( new FlowLayout(FlowLayout.CENTER, 30,30));
  this.setBackground(Color.gray);
  this.add (Box.createRigidArea(new Dimension (1000, 60)));
  touchstory =  new JLabel ( new ImageIcon ("touchstory.gif")) ;
  this.add (touchstory);
  this.add (Box.createRigidArea(new Dimension (1000, 30)));

  NameListener nameListener = new NameListener();
  nameListener.setThis(namesPanel);

  for (int i = 0; i < namesButtons.length; i++){
    namesButtons[i] = new JButton(names[i]);
    namesButtons[i].setFont(new Font("Comic", Font.ITALIC, 20));
    namesButtons[i].setPreferredSize(new Dimension (200,134));
    namesButtons[i].setBorder
                  (BorderFactory.createCompoundBorder(
                      BorderFactory.createLineBorder(Color.gray,1),
                       BorderFactory.createLineBorder(Color.lightGray,2)));
    namesButtons[i].setBackground(MyColor.stringToColor
                                          ("dkOlive"));
    namesButtons[i].addActionListener(nameListener);
    namesPanel.add( namesButtons[i]) ;
  }

  this.add(namesPanel);
  this.setVisible(true);
}

//----------------------------------------------------
//----------INNER CLASS TO ACT ON NAME-BUTTON CLICKS--------
//-----------------------------------------------------

private class NameListener implements ActionListener{

  public JPanel localNamesPanel;
  public void setThis (JPanel thisPanel) {
    localNamesPanel = thisPanel;
  }

  public void actionPerformed (ActionEvent event) {
    Object source = event.getSource();
    String s = ((JButton)source).getText();
    //set the name of the child in currentChild for writing to DB
```

FirstScreen.java

```
      CurrentChild currentChild = CurrentChild.getInstance(s);

      //test code
      //currentChild.logtoDB();

      //write name of child to text log file
      FSout.println("child " + s );
      localNamesPanel.setVisible(false);
    }}}  }
```

Class CurrentChild

CurrentChild.java

```
// singleton class for current child
// contains current visit

import java.util.Date;
import sun.jdbc.odbc.*;
import java.sql.*;

public class CurrentChild{
  public String childName;
  public int visit = 9;
  public int correct;

  //private static CurrentChild myInstance;
  public static CurrentChild myInstance;

  private CurrentChild(String nameIn) {
    childName = nameIn;
    //output for testing purposes
    //System.out.println (childName);
  }

  public static CurrentChild getInstance(String nameIn) {
    if (myInstance == null) myInstance = new CurrentChild(nameIn);
    return myInstance ;
  }

  //appends one log row to database
  public void logtoDB(String story, boolean isCorrect){
    Date d = new Date();
    String s = d.toString();
    try{
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver") ;
    }
    catch   (java.lang.ClassNotFoundException e) {
      System.out.println ( "error at Class.forName " + e);
    }
    try {
      String url = "jdbc:odbc:storydb";
      Connection con = DriverManager.getConnection(url);
      Statement stmt = con.createStatement();
```

CurrentChild.java

```
      String u1 = new String
        ("insert into child values ('" + childName + " ' , '" + visit +
         " ' , ' " + s + " ' , '"+ story + "' , '"+ isCorrect +" ' )");
      stmt.executeUpdate(u1);
    }
    catch (java.sql.SQLException e) {
      System.out.println (  "SQL exception at connect " + e);
    }
  }
}
```

Class Dragger2

Dragger2.java

```
// this presents t-story games
// calls Game, LastScreen, CurrentChild

import java.awt.*;

import javax.swing.*;
import java.awt.event.*;
import java.util.Date;

public class Dragger2 extends JPanel{
  private Game game = new Game();
  private Story[]stories  =  game.stories;
  private int si = 0;
  private Story currentStory = stories[si];
  private boolean newStory = true;
  private boolean repeatStory = false;
  private boolean firstStoryf = true;
  private int maxStoryLength = 5;
  boolean storyLogged = false;
  boolean correctAnswer = false;

  private JButton[] pictureButtons =new JButton[maxStoryLength];
  private JButton[] optionButtons =new JButton
                               [currentStory.optionIcons.length];
  private JLabel[] optionLabels = new JLabel
                                 [currentStory.optionIcons.length];

  private JButton previous, next, again, arrange;
  private JLabel info1;
  private JLabel o1, o2, o3;

  private JPanel storyPanel = new JPanel();
  private JPanel optionsPanel, pagePanel, navigationPanel;
  private JLayeredPane layeredPane;
  private MyOut out;
  private Component currentlyDragging;
  int myDelay = 2;
```

```
//Color myBlue = new Color (170,170,240);
Color myBlue = Color.gray;

public Dragger2(MyOut out){
  //make output file
  this.out = out;

  //setSize (1200,800); //doesn't appear to do anything

  //has some small effect on layout
  setLayout ( new BoxLayout (this, BoxLayout.Y_AXIS ));

  //-------------------------------------------------------
  //set up buttons for story panel and add story action listeners
  //-------------------------------------------------------

  StoryListener storyactionListener = new StoryListener();
  for (int i = 0; i < pictureButtons.length; i++){
    if (i < currentStory.storyIcons.length) {
      pictureButtons[i] = createPictureButton
          (currentStory.storyIcons[i]);
    }
    else  {
      //the first story is less than the max length,
      //we need to set up the
      // button and add a listener even though will not add it
      //to picture panel
      pictureButtons[i] = createPictureButton
                              (currentStory.storyIcons[0]);
    }
    pictureButtons[i].addActionListener(storyactionListener);
  }

  //---------------------------------------------------
  //set up options as buttons

  OptListener actionListener = new OptListener();
  for (int i = 0; i < currentStory.optionIcons.length; i++){
    optionButtons[i] = createOptionButton
                    (currentStory.optionIcons[i]);
  }

  //------------------------------------------------------
  // set up options as label and add drag listener
  for (int i = 0; i < currentStory.optionIcons.length; i++){
    optionLabels[i] = createOptionLabel
                              (currentStory.optionIcons[i]);
    optionLabels[i].setIcon(currentStory.optionIcons[i]);
    Dragger dragListener = new Dragger(i);
    optionLabels[i].addMouseMotionListener(dragListener);
    optionLabels[i].addMouseListener(dragListener);
  }

  //------------------------------------------------------
```

```
    //create options panel and option add buttons
    //used by next/again/previous

    optionsPanel = new JPanel();
    optionsPanel.setLayout (new BoxLayout (optionsPanel,
                                          BoxLayout.X_AXIS));
    optionsPanel.setBackground(Color.red);
    for (int i = 0; i < currentStory.optionIcons.length; i++){
      optionsPanel.add (optionButtons[i],new Integer (1));
      optionsPanel.add (Box.createRigidArea (new Dimension (15, 1)));
    }

    //----------------------------------
    //layout story panel
    //--------------------------------------

    storyPanel.setLayout(new FlowLayout (FlowLayout.CENTER,0,65));
    storyPanel.setPreferredSize(new Dimension (1135,300));

    for( int i = 0; i < currentStory.storyIcons.length; i++){
      storyPanel.add (pictureButtons[i]);
    }

    storyPanel.setBackground(Color.gray);
    storyPanel.setBorder
      (BorderFactory.createCompoundBorder(
        BorderFactory.createLineBorder(Color.lightGray,8),
          BorderFactory.createLineBorder(Color.gray,2)));

    //--------------------------------
    // put story nicely on screen
    //----------------------------------

    pagePanel = new JPanel();
    pagePanel.setPreferredSize (new Dimension (1018, 350));
    pagePanel.setBackground (Color.gray);
    pagePanel.setLayout (new FlowLayout (FlowLayout.CENTER, 20,10));
    pagePanel.add (Box.createRigidArea(new Dimension (700, 20)),
                                               new Integer (1));
    pagePanel.add(storyPanel, new Integer (1));
    pagePanel.add (Box.createRigidArea(new Dimension (700, 15)),
                                                new Integer (1));
    //-----------------------------------
    // create layered pane
    //-------------------------------------
    layeredPane = new JLayeredPane();
    ////sizing layered pane is crucial
    layeredPane.setPreferredSize ( new Dimension  (1018,680));
    layeredPane.setLayout (null);
    layeredPane.add(pagePanel, new Integer(1));
    Insets insets = layeredPane.getInsets();
    pagePanel.setBounds (insets.left, insets.top, 1018,350);
    pagePanel.setVisible(true);

    //----------------------------------------
```

```
    //add options labels
    //-------------------------------------
    int across = 126;
    for (int i = 0; i < currentStory.optionIcons.length; i++){
      layeredPane.add (optionLabels[i],new Integer (0));
      optionLabels[i].setBounds( across + insets.left,
                                   400 + insets.top, 200, 134);
      across = across + 290;
      ////System.out.println (insets.left);
      ////System.out.println (insets.top);
    }

    //-------------------------------------------
    //create navigation panel
    //--------------------------------------------
    NavListener navactionListener = new NavListener();
    navigationPanel = new JPanel();
    navigationPanel.setPreferredSize(new Dimension  (1018,100));

    again = new JButton ("again");
    again.setPreferredSize(new Dimension  (100, 50));
    again.addActionListener(navactionListener);
    navigationPanel.add(again);

    next = new JButton ("next");
    next.setPreferredSize(new Dimension  (100, 50));
    next.addActionListener(navactionListener);
    navigationPanel.add(next);

    //-------------------------------------------
    //set up frame
    //--------------------------------------------
    this.setBackground (Color.gray);
    add (layeredPane);
    add(navigationPanel);
  }

  //---------------------------------------------------
  //create buttons
  //---------------------------------------------------
  private JButton createPictureButton (Icon  icon){
    JButton picButton = new JButton (icon);
    picButton.setBorder(BorderFactory.createCompoundBorder(
      BorderFactory.createLineBorder(Color.gray,6),
        BorderFactory.createLineBorder(Color.lightGray,2)));
    return picButton;
  }

  private JButton createOptionButton (Icon icon){
    JButton picButton = new JButton (icon);
    picButton.setBorder(BorderFactory.createCompoundBorder(
      BorderFactory.createLineBorder(Color.gray, 2),
        BorderFactory.createLineBorder(Color.lightGray, 2)));
    return picButton;
  }
```

```
  private JLabel createOptionLabel (Icon icon){
    JLabel picLabel = new JLabel (icon);
    return picLabel;
  }

//-----------------------------------
//----------MAIN-----------------
//--------------------------------
/*
 // to run as main class
  public static void main(String[] args) {
   JFrame frame = new JFrame ("TouchStory Dragger");
   frame.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
   JComponent newContentPane = new Dragger2();
   newContentPane.setOpaque(true);
   frame.setContentPane(newContentPane);
   frame.pack();
   frame.setVisible(true);
  }
*/

  public void dispose(){
    System.out.println("ccc");
    System.exit(0);
  }

//--------------------------------------------------
//----------INNER CLASS TO ACT ON OPTION BUTTON CLICKS--------
//---------------------------------------------------

private class OptListener implements ActionListener{
  public void actionPerformed (ActionEvent event) {
/*  currently no option buttons are used
    Object source = event.getSource();
    pictureButtons[2].setIcon (((JButton)source).getIcon());
    if (((JButton)source).getIcon()==
      currentStory.optionIcons[currentStory.rightanswer]){
          optionsPanel.setVisible(false);
    }
*/
 }}

//--------------------------------------------------
//----------INNER CLASS TO ACT ON STORY BUTTON CLICKS--------
//---------------------------------------------------

private class StoryListener implements ActionListener{
  public void actionPerformed (ActionEvent event) {
  //not currently used
}}

//---------------------------------------------
//-----------INNER CLASS TO ACT ON NAVIGATION BUTTON CLICKS
//----------------------------------------------
```

```
private class NavListener implements ActionListener{
  public void actionPerformed (ActionEvent event) {
    Object source = event.getSource();
    optionsPanel.setVisible(true);

    //NEXT BUTTON HEARD
    //next is briefly disabled at the start of a new story
    //to avoid a child accidentally
    //pressing NEXT twice idempotent
    if (source == next && newStory == false  ){
      newStory = true;
      repeatStory  = false;
      storyLogged = false;
      int oldLength =  currentStory.storyIcons.length;
      si++
      if (si == stories.length){
        //check whether at end, if so finish
        JComponent lastContentPane = new LastScreen();
        lastContentPane.setOpaque(true);
        JFrame frame = new JFrame();
        frame.setContentPane(lastContentPane);
        frame.pack();
        frame.setVisible(true);
      };
      currentStory = stories[si];
      System.out.println("next story " + currentStory.sname);
      out.println(" ");
      out.println("next story " + currentStory.sname);

      if  (currentStory.storyIcons.length  < oldLength ){
        storyPanel.setVisible (false);
        for (int i =  currentStory.storyIcons.length ; i < oldLength;i++ ){
          storyPanel.remove(currentStory.storyIcons.length);
        }
        storyPanel.setVisible (true);
      }

      if  (currentStory.storyIcons.length  > oldLength ){
          for (int i = oldLength; i <
                  currentStory.storyIcons.length ; i++ ){
            storyPanel.add(pictureButtons[i]) ;
          }
      }

      for (int i = 0; i < currentStory.storyIcons.length; i++){
        pictureButtons[i].setIcon(currentStory.storyIcons[i]);
      }

      for (int i = 0; i < currentStory.optionIcons.length; i++){
        optionLabels[i].setIcon(currentStory.optionIcons[i]);
        optionLabels[i].setVisible (true);
      }

      optionLabels[0].setLocation (126,400);
```

```
      layeredPane.setLayer(optionLabels[0],0);

      optionLabels[1].setLocation (416,400);
      layeredPane.setLayer(optionLabels[1],0);

      optionLabels[2].setLocation (706,400);
      layeredPane.setLayer(optionLabels[2],0);

    } else if (source == again ) { ///AGAIN Button HEARD
      System.out.println("repeating story " + currentStory.sname);
      out.println("repeating story " + currentStory.sname);
      newStory = false;
      repeatStory = true;

      for (int i = 0; i < currentStory.storyIcons.length; i++){
        pictureButtons[i].setIcon(currentStory.storyIcons[i]);
      }

      optionLabels[0].setLocation (126,400);
      optionLabels[0].setVisible(true);
      layeredPane.setLayer(optionLabels[0],0);

      optionLabels[1].setLocation (416,400);
      optionLabels[1].setVisible(true);
      layeredPane.setLayer(optionLabels[1],0);

      optionLabels[2].setLocation (706,400);
      optionLabels[2].setVisible(true);
      layeredPane.setLayer(optionLabels[2],0);

    } else if (source == previous){ ///PREVIOUS BUTTON HEARD
      // previous button no longer in use
      newStory = true;
      repeatStory = false;
      int oldLength =  currentStory.storyIcons.length;

      if (si >0){si--;}  // mustn't go off end of array
      currentStory = stories[si];
      System.out.println("previous story " + currentStory.sname);
      out.println("previous story " + currentStory.sname);

      if  (currentStory.storyIcons.length  < oldLength ){
        storyPanel.setVisible (false);
        for (int i =  currentStory.storyIcons.length ;
                               i < oldLength; i++ ){
          storyPanel.remove(i);
        }
        storyPanel.setVisible (true);
      }

      if  (currentStory.storyIcons.length  > oldLength ){
        for (int i = oldLength;
                 i < currentStory.storyIcons.length ; i++ ){
          storyPanel.add(pictureButtons[i]) ;
        }
```

```
      }
      /////////////////////////////////

      for (int i = 0; i < currentStory.storyIcons.length; i++){
        pictureButtons[i].setIcon(currentStory.storyIcons[i]);
      }
      for (int i = 0; i < currentStory.optionIcons.length; i++){
         optionLabels[i].setIcon(currentStory.optionIcons[i]);
         optionLabels[i].setVisible (true);
      }
      optionLabels[0].setLocation (126,400);
      layeredPane.setLayer(optionLabels[0],0);

      optionLabels[1].setLocation (416,400);
      layeredPane.setLayer(optionLabels[1],0);

      optionLabels[2].setLocation (706,400);
      layeredPane.setLayer(optionLabels[2],0);

    }
  }
}

//---------------------------------------------------------------
//-----------------INNER DRAGGER CLASS-------------------------
//---------------------------------------------------------------

//logs to both system.out and output file, might want MVC architecture

class Dragger extends MouseAdapter implements MouseMotionListener{
  Point press = new Point();
  boolean dragging = false;
  String status = "init"; //whether the icon has been dragged
  boolean isCorrect; //is this option the correct answer
  int movedCount = 0; //used to reduce the number of positions logged
  int optionindex;  //which option is it
  int b; //which picture is the blank one
  int redraw = 0;

  public Dragger (int i){
    super();
    optionindex = i;
  }

  public void mousePressed (MouseEvent event) {
    press.x = event.getX();
    press.y = event.getY();
    dragging = true;
    //System.out.println("in mouse pressed");

    if (firstStoryf){
      System.out.println();
      System.out.println ((new Date()).toString());
      System.out.println("story " + currentStory.sname);
      out.println("");
```

```
      out.println ((new Date()).toString());
      out.println("story " + currentStory.sname);
      firstStoryf = false;
    }
    Component c = (Component)event.getSource();
    currentlyDragging = c;

    isCorrect = (((JLabel)c).getIcon()==
              currentStory.optionIcons[currentStory.rightanswer]);

    Date d = new Date();
    System.out.println ("time " + d.getHours()+ ":"
                             +d.getMinutes()+":"+ d.getSeconds());
    out.println ("time " + d.getHours()+ ":" +d.getMinutes()+":"+
                             d.getSeconds());

    if (isCorrect){
      System.out.println("option "+ optionindex + " (correct)
                                              selected")  ;
      out.println("option "+ optionindex + " (correct) selected")  ;
    }
    else  {
      System.out.println ("option " + optionindex + " (wrong)
                           selected") ;
      out.println ("option " + optionindex + " (wrong) selected") ;
    }

    if (newStory){
      status = "init";
      newStory = false;
    }

    if (repeatStory)status = "init";
    layeredPane.setLayer(c,8);
    layeredPane.moveToFront(c);
  }

  public boolean isDragging () {
    return dragging;
  }

  public void mouseReleased (MouseEvent event){
    //dragging = false;
  }

  public void mouseClicked (MouseEvent event){
    //dragging = false;
  }

  public void mouseMoved (MouseEvent event){
    Component c = (Component)event.getSource();

    if (c == currentlyDragging){
      press.x = event.getX();
      press.y = event.getY();
```

```
      //System.out.println ("in mM");
      this.mouseDragged(event);
    }
  }

  public void mouseDragged (MouseEvent event){
    //System.out.println ("in mouse dragged");
    Component c = (Component)event.getSource();
    layeredPane.moveToFront(c);
    if (dragging) {
      // System.out.println ("in mouse dragged  and dragging");
      Point loc = c.getLocation();
      Point pt = new Point();

      //move to new location
      pt.x =   event.getX() + loc.x - press.x;
      pt.y =   event.getY() + loc.y  - press.y ;

      //only redraw every third location to speed travel
      //across screen
      redraw++;
      if (redraw >= 2 ){
        if (Math.abs(pt.x - loc.x) > 15 ||  Math.abs(pt.y - loc.y)
                                                          > 15){
          redraw = 0;
          c.setLocation (pt.x,pt.y);
        }
      }

      //decide whether to log
      if (movedCount == 8){
        System.out.println("option " + optionindex+ " at "+ pt.x
                                               +"   "+ pt.y);
        out.println ("option " + optionindex+ " at "+ pt.x
                                              +"   "+ pt.y);
        movedCount = 0;
      } else {
          movedCount++;
      }

      //check whether at target
       b = currentStory.posblank;
       Component cb = storyPanel.getComponent(b);
       if (pt.x < (cb.getX ()+ 60) && pt.x > (cb.getX ()- 120)
                                 && pt.y < 180)  {
         if (! storyLogged) {
           CurrentChild currentChild = CurrentChild.getInstance(" ");
           currentChild.logtoDB(currentStory.sname, isCorrect);
           storyLogged = true;
         };

         if  (isCorrect) {
           correctAnswer = true;
           System.out.println("option " + optionindex+" fitting");
           out.println("option " + optionindex+" fitting*********");
```

Dragger2.java

```
            dragging = false;
            pictureButtons[currentStory.posblank].setIcon
                                     (((JLabel)c).getIcon());

            for (int i = 0; i < currentStory.optionIcons.length; i++){
              optionLabels[i].setVisible (false);
            }

            c.getParent().repaint();

          } else { ///is not correct
            c.setLocation( cb.getX() - 49,  cb.getY() + 48        );
            if  (status != "fitting") {
              System.out.println ("option " + optionindex+" fitting");
              out.println ("option " + optionindex+" fitting------") ;
              status = "fitting";
            }
          }
        }

        // check whether near target
        if  (status   == "moved" &&  pt.y < 150  ) {
          status = "near";
          System.out.println (  " near"  );
          System.out.println ("option " + optionindex+ " at "+
                                        pt.x  +"   "+ pt.y );
          out.println ("option " + optionindex+ " at "+ pt.x  +
                                            "   "+ pt.y );
        }

        //check if moved
        if ( status  == "init"){
         status  = "moved";
        }
      }
   }
} //end of Dragger
} //end of Dragger2
```

Class Game

Game.java

```
//sets up the t-story games for a session
//calls Story and CurrentChild

import java.awt.*;
import sun.jdbc.odbc.*;
import java.sql.*;
import java.io.*;
import java.util.Random; // ++++++++++++

////////////////////////////////////////////
//Database tables used
```

Game.java

```
//game, optionpics, storypics, drawnstories
////////////////////////////////////////////


public class Game {
  public Story[]stories;

  private    String [] storypics;
  private    String [] optionpics;
  private    int pos_blank;
  private    int pos_right_answer;
  private    int story_id;
  private    int story_length, i_stories_length, d_stories_length;
  private    String name, blank;
  private    String pic;
  private    Story tempStory; //===========
  private    int  nextRand;//================
  private    Random gen = new Random();
  private    String thischild ="x";

  public Game () {
    //link to database
    try{
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver") ;
    }
    Catch (java.lang.ClassNotFoundException e) {
      System.out.println ( "error at Class.forName " + e);
    }
    try {
      String url = "jdbc:odbc:storydb";
      Connection con = DriverManager.getConnection(url);
      Statement stmt = con.createStatement();
      ResultSet r,r1;

      //////////////////////////////////////////////
      // this is very dodgy
      //the declaration has to be here with command line
      //access to give chance
      // for currentChild to be set up.
      // was OK with JBuiilder
      //////////////////////////////////////////
      String currentChild = CurrentChild.myInstance.childName;
      thischild = currentChild;
      //////////////////////////////////////////////////

      // SQL for how many stories are there?
      // first count those with software generated images

      String q2 = new String
       ("SELECT count (game_id) FROM (SELECT Game.game_id, Game.name, Game.type,
       Game.pos_correct, Game.posn_blank, Optionpics.count_opt_pics,
       Optionpics.opic1, Optionpics.opic2, Optionpics.opic3, Optionpics.opic4,
       Optionpics.opic5, Optionpics.opic6, Optionpics.opic7, Optionpics.opic8,
       Optionpics.opic9, Storypics.blank, Storypics.count_story_pics,
       Storypics.pic1, Storypics.pic2, Storypics.pic3, Storypics.pic4,
```

```
 Storypics.pic5, Storypics.pic6, Storypics.pic7, Storypics.pic8,
 Storypics.pic9 FROM "+  thischild  +  ", Storypics INNER JOIN (Optionpics
 INNER JOIN Game ON Optionpics.optionpicsid=Game.optionpicsid) ON
 Storypics.storypicsid=Game.storypicsid "+   "WHERE "+   thischild
 +".name=Game.name  ORDER BY game_id)");

r = stmt.executeQuery(q2);
while (r.next()) {
 i_stories_length = r.getInt(1) ;
}
r.close();

// then count those based on picture files (.gif and .jpegs)
String q3 = new String
 ("SELECT count (gameid) FROM ( SELECT drawnStories.gameId,
 drawnStories.name, drawnStories.shape, drawnStories.back,
 drawnStories.fore, drawnStories.length, drawnStories.shapeo1,
 drawnStories.backo1, drawnStories.foreo1, drawnStories.sizeo1,
 drawnStories.posno1, drawnStories.shapeo2, drawnStories.backo2,
 drawnStories.foreo2, drawnStories.sizeo2, drawnStories.posno2,
 drawnStories.posn_correct, drawnStories.posn_blank, drawnStories.blank,
 drawnStories.type FROM drawnStories, " + thischild +   " WHERE
 drawnStories.name= "+ thischild +".name ORDER BY gameId )");

r = stmt.executeQuery(q3);

while (r.next()) {
 d_stories_length =  r.getInt(1) ;
}
r.close();
story_length = i_stories_length + d_stories_length;

// create an array of the correct length
stories = new Story[story_length];

String q4   =
 ("SELECT * FROM "+
 "( SELECT drawnStories.gameId, drawnStories.name, drawnStories.shape,
 drawnStories.back, drawnStories.fore, drawnStories.length,
 drawnStories.shapeo1, drawnStories.backo1, drawnStories.foreo1,
 drawnStories.sizeo1, drawnStories.posno1, drawnStories.shapeo2,
 drawnStories.backo2, drawnStories.foreo2, drawnStories.sizeo2,
 drawnStories.posno2, drawnStories.posn_correct, drawnStories.posn_blank,
 drawnStories.blank, drawnStories.type "+
 "FROM drawnStories, " + thischild +
 " WHERE drawnStories.name= "+ thischild +".name ORDER BY gameId )");

r = stmt.executeQuery(q4);

for (int j = 0; j < d_stories_length; j++) {
  //create and add drawn stories to stories array
  r.next();
  stories[j] = new Story(
  //story panels
  r.getString ("shape"),
```

```
    MyColor.stringToColor (r.getString ("back")),
    MyColor.stringToColor (r.getString ("fore")),
    r.getInt("length"),
    //first distracter
    r.getString ("shapeo1"),
    MyColor.stringToColor(r.getString("backo1")),
    MyColor.stringToColor(r.getString("foreo1")),
    r.getInt ("sizeo1"),
    r.getInt ("posno1"), //opt1
    //second distracter
    r.getString ("shapeo2"),
    MyColor.stringToColor (r.getString ("backo2")),
    MyColor.stringToColor (r.getString ("foreo2")),
    r.getInt ("sizeo2"),
    r.getInt ("posno2"),
    r.getInt ("posn_correct"), // posn correct answer in options
    r.getInt ("posn_blank"),   //posn of blank in panel sequence
    r.getInt ("gameId"),
    r.getString ("name"));
  }
  r.close();

  // create and add stories based on picture files
  String q1 = new String
   ("SELECT * FROM (SELECT Game.game_id, Game.name, Game.type,
   Game.pos_correct, Game.posn_blank, Optionpics.count_opt_pics,
   Optionpics.opic1, Optionpics.opic2, Optionpics.opic3, Optionpics.opic4,
   Optionpics.opic5, Optionpics.opic6, Optionpics.opic7, Optionpics.opic8,
   Optionpics.opic9, Storypics.blank, Storypics.count_story_pics,
   Storypics.pic1, Storypics.pic2, Storypics.pic3, Storypics.pic4,
   Storypics.pic5, Storypics.pic6, Storypics.pic7, Storypics.pic8,
   Storypics.pic9 FROM "+ thischild  + ", Storypics INNER JOIN (Optionpics
   INNER JOIN Game ON Optionpics.optionpicsid=Game.optionpicsid) ON
   Storypics.storypicsid=Game.storypicsid "+ "WHERE "+  thischild
   +".name=Game.name  ORDER BY game_id)");

  r = stmt.executeQuery(q1);

  //needs moving down array
  for (int j = d_stories_length; j < story_length; j++) {
    r.next() ;
    name = r.getString("name");
    pos_right_answer = r.getInt("pos_correct");
    pos_blank = r.getInt("posn_blank");
    story_id = r.getInt("game_id");
    blank = r.getString ("blank");

    storypics = new String [r.getInt("count_story_pics")];
      for (int i = 0; i < storypics.length; i++){
        storypics[i] = r.getString(i + 18);
        //System.out.println(storypics[i]);
      }
      storypics[pos_blank] = blank;

      optionpics = new String [r.getInt("count_opt_pics")];
```

```
          for (int i = 0; i < optionpics.length; i++){
            optionpics[i] = r.getString(i + 7);
            //System.out.println (optionpics[i]);
          }

          stories[j] = new Story (storypics,optionpics, pos_right_answer,
                                  pos_blank, story_id, name);
       } //end for j

      r.close();

      //code to shuffle array. Used in trial 2
      /*
       for (int j = 0; j < stories.length; j++){
           nextRand = Math.abs(gen.nextInt())% stories.length;
           tempStory = stories[j];
           stories[j] = stories[nextRand];
           stories[nextRand] = tempStory;
       }
      */
    }
    catch (java.sql.SQLException e) {
      System.out.println (  "SQL exception at connect " + e);
    }
  }
  public static void main(String[] args) throws Exception {
     //to run as main
     //Game game = new Game();
     //System.in.read();     //stops the standard input window closing
  }  // end main
}
```

Class Story

Story.java

```
//software drawn stories
//calls a variety of story classes providing drawn images
//e.g. MyEclipse, MyCross

import javax.swing.*;
import java.awt.*;

public class Story {

  public Icon[] storyIcons, optionIcons;
  public int rightanswer;   //posn of correct answer in options 0/1/2
  public int posblank;      //posn of blank in presented story
  public String sname;
  public int sid;

  private int shapeToInt (String shape){
    int s = 0;
    if (shape.equals( "oval"))       s= 1;
    else if (shape.equals( "rect"))  s= 2;
    else if (shape.equals( "cross")) s= 3;
    else if (shape.equals("moon"))   s= 4;
    else if  (shape.equals("door"))  s= 5;
    else if  (shape.equals("eclipse"))  s= 6;
    else if (shape.equals("egg"))       s = 7;
    return s;
  }

  //constructor for image icons
  public Story (String[] storyPics, String[] optionPics, int ans,
    int positionofBlank,      int psid, String psname){
    storyIcons = new Icon [storyPics.length];
    optionIcons = new Icon [optionPics.length];
    rightanswer = ans;
    posblank = positionofBlank;
    sname = psname;

    for (int i = 0; i<storyPics.length; i++){
      storyIcons[i] = new ImageIcon (storyPics[i]);
    }

    for (int i = 0; i<optionPics.length; i++){
      optionIcons[i] = new ImageIcon (optionPics[i]);
    }
  }

  //constructor for generated icons
  public Story (
    String shape, Color back, Color fore, int length, //main story
    String o1shape,Color o1back, Color o1fore, int o1size, int o1pos, //opt1
    String o2shape,Color o2back, Color o2fore, int o2size, int o2pos, //opt2
    int ans, // posn correct answer in options
    int positionofBlank, //posn of blank in story as presented
    int psid,  String psname){
```

```
    storyIcons = new Icon [length];
    optionIcons = new Icon [3]; //for now
    rightanswer = ans;
    posblank = positionofBlank;
    sname = psname;
    //encode shapes
    int s = shapeToInt (shape);

    //assign icons to story icon array and right answer in options
    switch (s){
      case 0:
        for (int i = 0; i<length; i++){
          storyIcons[i] = new MyCross (back, fore, 200, 134, i+1);
        }
        optionIcons[rightanswer] =
                      new MyCross(back, fore, 200, 134, posblank+1);
        break;
      case 1 :
        for (int i = 0; i<length; i++){
          storyIcons[i] = new MyOval (back, fore, 200, 134, i+1);
        }
        optionIcons[rightanswer] =
                       new MyOval(back, fore, 200, 134, posblank+1);
        break;
      case 2 :
        for (int i = 0; i<length; i++){
          storyIcons[i] = new MyRect (back, fore, 200, 134, i+1);
        }
        optionIcons[rightanswer] =
                       new MyRect(back, fore, 200, 134, posblank+1);
        break;
      case 3 :
        for (int i = 0; i<length; i++){
          storyIcons[i] = new MyCross (back, fore, 200, 134, i+1);
        }
        optionIcons[rightanswer] =
                        new MyCross(back, fore, 200, 134, posblank+1);
        break;
      case 4 :
        for (int i = 0; i<length; i++){
          storyIcons[i] =
                        new MyMoon (back, fore, 200, 134, i+1);
        }
        optionIcons[rightanswer] =
                        new MyMoon(back, fore, 200, 134, posblank+1);
        break;
      case 5 :
        for (int i = 0; i<length; i++){
          storyIcons[i] = new MyDoor (back, fore, 200, 134, i+1);
        }
        optionIcons[rightanswer] =
                        new MyDoor(back, fore, 200, 134, posblank+1);
        break;
      case 6 :
```

```
    for (int i = 0; i<length; i++){
      storyIcons[i] = new MyEclipse (back, fore, 200, 134, i+1);
    }
    optionIcons[rightanswer] =
                     new MyEclipse(back, fore, 200, 134, posblank+1);
    break;
  case 7 :
    for (int i = 0; i<length; i++){
      storyIcons[i] = new MyEgg (back, fore, 200, 134, i+1);
    }
    optionIcons[rightanswer] =
                     new MyEgg(back, fore, 200, 134, posblank+1);
    break;
  default:
    System.out.println("no valid cases");
  }

  //overwrite space to be blank with blank gif
  storyIcons[posblank] = new ImageIcon ("newBlank.gif");

  //assign distracters
  s = shapeToInt (o1shape);
  switch (s){
    case 1 :
      optionIcons[o1pos] =
                     new MyOval(o1back, o1fore, 200, 134, o1size);
      break;
    case 2 :
      optionIcons[o1pos] =
                     new MyRect(o1back, o1fore, 200, 134, o1size);
      break;
    case 3 :
      optionIcons[o1pos] =
                     new MyCross(o1back, o1fore, 200, 134, o1size);
      break;
    case 4 :
      optionIcons[o1pos] =
                     new MyMoon(o1back, o1fore, 200, 134, o1size);
      break;
    case 5 :
      optionIcons[o1pos] =
                     new MyDoor(o1back, o1fore, 200, 134, o1size);
      break;
    case 6 :
      optionIcons[o1pos] =
                     new MyEclipse(o1back, o1fore, 200, 134, o1size);
      break;
    case 7 :
      optionIcons[o1pos] =
                     new MyEgg(o1back, o1fore, 200, 134, o1size);
      break;
  }

  s = shapeToInt (o2shape);
  switch (s){
```

Story.java

```
        case 1 :
          optionIcons[o2pos] =
                       new MyOval(o2back, o2fore, 200, 134, o2size);
          break;
        case 2 :
          optionIcons[o2pos] =
                       new MyRect(o2back, o2fore, 200, 134, o2size);
          break;
        case 3 :
          optionIcons[o2pos] =
                        new MyCross(o2back, o2fore, 200, 134, o2size);
          break;
        case 4 :
          optionIcons[o2pos] =
                        new MyMoon(o2back, o2fore, 200, 134, o2size);
          break;
        case 5 :
          optionIcons[o2pos] =
                        new MyDoor(o2back, o2fore, 200, 134, o2size);
          break;
        case 6 :
          optionIcons[o2pos] =
                        new MyEclipse(o2back, o2fore, 200, 134, o2size);
          break;
        case 7 :
          optionIcons[o2pos] =
                        new MyEgg(o2back, o2fore, 200, 134, o2size);
          break;
    }
  }
}
```

Class MyEclipse

Note that there are a number of classes used to create the various program generated t-stories. Two examples are given here, MyEclipse followed by MyCross

MyEclipse.java

```
// an eclipse icon (based on overlapping ovals)

import java.awt.*;
import javax.swing.*;

public class MyEclipse implements Icon{

  private  Color back, fore;
  private int w, h;  //width and height of icon
  private int size;  //size of figure (1 to 5)

  public MyEclipse(Color back, Color fore, int w, int h, int size) {
    this.back = back;
    this.fore = fore;
```

MyEclipse.java

```
    this.w = w;
    this.h = h;
    this.size = size;
  }
  public void paintIcon(Component c, Graphics g, int x, int y) {
    g.setColor(Color.lightGray );
    g.fillRect(x+1, y+1, w-2, h-2);
    g.setColor(back);
    g.fillOval( x+20, y +12, w-40, h-24);
    g.setColor(fore);
    switch (size) {
      case 1 : g.fillOval(x-65, y+12, w-20, h-24) ;   break;
      case 2 : g.fillOval(x-40, y+12, w-20, h-24) ;   break;
      case 3 : g.fillOval(x-15, y+12, w-20, h-24) ;   break;
      case 4 : g.fillOval(x+10, y+12, w-20, h-24) ;   break;
      case 5 : g.fillOval(x+35, y+12, w-20, h-24) ;   break;
      default :  g.fillOval(x+25, y+25, w-50, h-50) ; break;
    }
  }

  public int getIconWidth(){return w;}
  public int getIconHeight(){return h;}

}
```

Class MyCross

MyCross.java

```
//a cross icon (made of two rectangles at 90 degrees)

import java.awt.*;
import javax.swing.*;

public class MyCross implements Icon{

  private  Color back, fore;
  private int w, h;  //width and height of icon
  private int size;  //size of figure (1 to 5)

  public MyCross(Color back, Color fore, int w, int h, int size) {
    this.back = back;
    this.fore = fore;
    this.w = w;
    this.h = h;
    this.size = size;
  }

  public void paintIcon(Component c, Graphics g, int x, int y) {
    g.setColor(back);
    g.fillRect(x, y, w, h);
    g.setColor(fore);
    switch (size) {
      case 1   :
```

MyCross.java

```
        g.fillRect(x+30, y+45, w-60, h-90);
        g.fillRect(x+75, y+18, w-150, h-36);
        break;
      case 2 :
        g.fillRect(x+40, y+50, w-80, h-100);
        g.fillRect(x+80, y+25, w-160, h-50);
        break;
      case 3 :
        g.fillRect(x+50, y+55, w-100, h-110);
        g.fillRect(x+85, y+32, w-170, h-64);
        break;
      case 4 :
        g.fillRect(x+60, y+60, w-120, h-120);
        g.fillRect(x+90, y+39, w-180, h-78);
        break;
      case 5 :
        g.fillRect(x+69, y+63, w-138, h-126);
        g.fillRect(x+94, y+43, w-188, h-86);
        break;
    }
  }

  public int getIconWidth(){return w;}
  public int getIconHeight(){return h;}

}
```

Class LastScreen

LastScreen.java

```
// final screen

import java.awt.*;
import javax.swing.*;
import java.awt.event.*;

public class LastScreen extends JPanel{

  private JLabel touchstory;

  public LastScreen (){
    this.setPreferredSize (new Dimension (1018, 750));
    this.setLayout ( new FlowLayout(FlowLayout.CENTER, 30,30));
    this.setBackground(Color.gray);
    this.add (Box.createRigidArea(new Dimension (1000, 60)));
    touchstory =  new JLabel ( new ImageIcon ("thankyou1.gif")) ;
    this.add (touchstory);
    this.add (Box.createRigidArea(new Dimension (1000, 30)));
    this.setVisible(true);
  }
}
```

Class Populate

Populate.java

```
// to populate the tables for each child
// the names of participants are hard coded
// clearly this would generalise better if they were
// retrieved from the database
// participant’s names have been made anonymous

import java.awt.*;
import sun.jdbc.odbc.*;
import java.sql.*;
import java.io.*;
/////////////////////////////////////////////
// database tables used
// adapt, schedule, table for each child
////////////////////////////////////////////

public class Populate {

  public Populate (int tsvisit){

    //link to database
    try{
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver") ;
    }
    catch   (java.lang.ClassNotFoundException e) {
      System.out.println ( "error at Class.forName " + e);
    }

    try {
      String url = "jdbc:odbc:storydb";
      Connection con = DriverManager.getConnection(url);
      Statement stmt = con.createStatement();
      Statement stmt2 = con.createStatement();
      Statement stmt3 = con.createStatement();
      Statement stmt4 = con.createStatement();
      ResultSet r,r1,r2;
      String q1 = new String();
      String q2 = new String();

      //////////////////////////////////////////////////////////
      //clear each child
      /////////////////////////////////////////////////////////
/*
      //these are the children used in trial 3
      q1 = ("DELETE * from Xcx");
      stmt.executeUpdate (q1);

      q1 = ("DELETE * from Xex");
      stmt.executeUpdate (q1);

      q1 = ("DELETE * from Xdx");
      stmt.executeUpdate (q1);
```

```
        q1 = ("DELETE * from Xjx");
        stmt.executeUpdate (q1);

        q1 = ("DELETE * from Xhx");
        stmt.executeUpdate (q1);

        q1 = ("DELETE * from Xnx");
        stmt.executeUpdate (q1);

*/      //in current use
        q1 = ("DELETE * from Megan1");
        stmt.executeUpdate (q1);

        q1 = ("DELETE * from Megan2");
        stmt.executeUpdate (q1);

        //////////////////////////////////////////////////////
        //reconstruct each child
        //////////////////////////////////////////////////////

/*
        q2 =  ("INSERT INTO Xcx " +
         "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
         adapt.stype=schedule.stype  "+
         "WHERE adapt.child= 'Xcx' And schedule.order<=adapt.tosee AND visit = " +
         tsvisit );

        stmt.executeUpdate (q2) ;
        System.out.println(" populated Xcx for visit " + tsvisit);
        //////////////////////////////////////////////////

        q2 =  ("INSERT INTO Xex " +
         "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
         adapt.stype=schedule.stype  "+"
         WHERE adapt.child= 'Xex' And schedule.order<=adapt.tosee AND visit = " +
         tsvisit );

        stmt.executeUpdate (q2) ;
        System.out.println(" populated Xex for visit " + tsvisit);
         //////////////////////////////////////////////////////////////

        q2 =  ("INSERT INTO Xjx " +
         "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
         adapt.stype=schedule.stype WHERE adapt.child= 'Xjx' And
         schedule.order<=adapt.tosee AND visit = " + tsvisit );

        stmt.executeUpdate (q2) ;
        System.out.println(" populated Xjx for visit " + tsvisit);
        ////////////////////////////////////////////////////////

        q2 =  ("INSERT INTO Xnx " +
         "SELECT schedule.name AS name  "+"FROM adapt INNER JOIN schedule ON
         adapt.stype=schedule.stype  "+"WHERE adapt.child= 'Xnx' And
         schedule.order<=adapt.tosee AND visit = " + tsvisit );
```

```
      stmt.executeUpdate (q2) ;
      System.out.println(" populated Xnx for visit " + tsvisit);
      //////////////////////////////////////////

      q2 =  ("INSERT INTO Xdx " +
       "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
       adapt.stype=schedule.stype WHERE adapt.child= 'Xdx' And
       schedule.order<=adapt.tosee AND visit = " + tsvisit );

      stmt.executeUpdate (q2) ;
      System.out.println(" populated Xdx for visit " + tsvisit);
      //////////////////////////////////////////////////

      q2 =  ("INSERT INTO Xhx " +
       "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
       adapt.stype=schedule.stype WHERE adapt.child= 'Xhx' And
       schedule.order<=adapt.tosee AND visit = " + tsvisit );
      stmt.executeUpdate (q2) ;
      System.out.println(" populated Harry for visit " + tsvisit);
*/

      q2 =  ("INSERT INTO Megan1 " +
       "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
       adapt.stype=schedule.stype WHERE adapt.child= 'Megan1' And
       schedule.order<=adapt.tosee AND visit = " + tsvisit );

      stmt.executeUpdate (q2) ;
      System.out.println(" populated Megan1 for visit " + tsvisit);

      q2 =  ("INSERT INTO Megan2 " +
       "SELECT schedule.name AS name FROM adapt INNER JOIN schedule ON
       adapt.stype=schedule.stype WHERE adapt.child= 'Megan2' And
       schedule.order<=adapt.tosee AND visit = " + tsvisit );
      stmt.executeUpdate (q2) ;
      System.out.println(" populated Megan2 for visit " + tsvisit);

    }//end of try block

    catch (java.sql.SQLException e) {
      System.out.println (  "SQL exception at connect " + e);
    }//end catch block
  }//end Populate constructer

  public static void main(String[] args) throws Exception {
    Populate pop = new Populate(Integer.parseInt(args [0]));
    System.in.read();     //stops the standard input window closing
  }//end main
}//end Populate class
```

Class TSAdapter2

TSAdapter2.java

```
// code to adapt t-stories to particular participants
// work on a batch basis

import java.awt.*;
import sun.jdbc.odbc.*;
import java.sql.*;
import java.io.*;
import java.util.Random; // ++++++++++++
////////////////////////////////////////////
// database tables used
// construction of log: log2, child, stories, map, extras
// adaptation: adaptQQ, toInc,adapt, toInc2
///////////////////////////////////////////

public class TSAdapter2 {
  private     Random gen = new Random();
  int nextRand;

  public TSAdapter2 (int tsvisit) {

    //adaptation is done on the most recent 4 visits from the most recent 6
    //to allow for occasional missed sessions
    int fromvisit = tsvisit -  6;

    //link to database
    try{
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver") ;
    }
    catch   (java.lang.ClassNotFoundException e) {
      System.out.println ( "error at Class.forName " + e);
    }

    try {
      String url = "jdbc:odbc:storydb";
      Connection con = DriverManager.getConnection(url);
      Statement stmt = con.createStatement();
      Statement stmt2 = con.createStatement();
      Statement stmt3 = con.createStatement();
      Statement stmt4 = con.createStatement();
      ResultSet r,r1,r2;
      String adaptQ = new String();
      boolean notyetfound = true;

      ////////////////////////////////////////////////////////
      //clear the log
      ///////////////////////////////////////////////////////
      String q2 = new String ("DELETE * FROM log2");
      stmt.executeUpdate (q2) ;
      System.out.println(" cleared log");

      //////////////////////////////////////////////////////
      //reconstruct the log with most recent 6 visits
      //////////////////////////////////////////////////////
```

```
q2 =  ("INSERT INTO log2 ( name, visit, logged, story, stype, correct )"
+ " SELECT child.name, child.visit, child.logged, child.story,
Stories.stype, map.correct "
+ " FROM (child INNER JOIN map ON child.isCorrect=map.isCorrect) "
+ " INNER JOIN Stories ON child.story=Stories.storyname "
+ " WHERE visit<=" + tsvisit + " AND visit>" + fromvisit
+ " ORDER BY child.name, child.visit" );

stmt.executeUpdate (q2) ;
System.out.println(" populated log");

/////////////////////////////////////////////////////////////
// reduce to 4 most recent visits per child from last 6
// NOTE that this does not generalise
// and becomes cripplingly slow with just a few repetitions
// ---better on a per child basis
/////////////////////////////////////////////////////////////


q2 = (" DELETE * FROM log2 AS lg2 WHERE exists "
+   " (select * from extras AS ex where  lg2.name = ex.name and lg2.visit
= ex.minvisit)");

stmt.executeUpdate (q2) ;
System.out.println(" deleted old 1");

stmt.executeUpdate (q2) ;
System.out.println(" deleted old 2");


///////////////////////////////////////////////////
//**identify those to decrease
///////////////////////////////////////////////////
String decQ = new String ("SELECT adaptQQ.name, adaptQQ.stype,
count(outcome) "
+ "FROM adaptQQ WHERE outcome=1 GROUP BY adaptQQ.name, adaptQQ.stype
HAVING count(outcome)>1 ");
r = stmt.executeQuery(decQ);

/////////////////////////////////////////////
//** identify those to increase
///////////////////////////////////////////
String incQ = new String ( "SELECT toInc.name, toInc.stype, toInc.Expr1002
"
+ "FROM toInc WHERE NOT EXISTS (select * from toDec "
+ "where name = toInc.name and stype = toInc.stype) " );
r = stmt.executeQuery(incQ);

System.out.println(" identified to inc and to dec");

/////////////////////////////////////////////////
//**apply decrease
////////////////////////////////////////////////
String doDec = new String ("UPDATE adapt SET tosee = tosee-1 "
+ "WHERE tosee >1 and EXISTS (select * from toDec "
```

```
        + "where name = adapt.child and stype = adapt.stype)");
        stmt.executeUpdate (doDec) ;
        System.out.println(" done dec");

        //////////////////////////////////////////////////
        //**applyinc
        /////////////////////////////////////////////////
        String doInc = new String ("UPDATE adapt SET tosee = tosee + 1  "
        //   + "WHERE tosee >1 and EXISTS (select * from toInc2 "
        + "WHERE EXISTS (select * from toInc2 "
        + "where name = adapt.child and stype = adapt.stype)");
        stmt.executeUpdate (doInc) ;
        System.out.println(" done inc");


        //////////////////////////////////////////////////
        // adjust number of t-stories to within range
        ///////////////////////////////////////////////////
        String q3 = new String ("SELECT adapt.child, Sum (tosee) as [countfw]  "
        + "from adapt group by child");
        r = stmt.executeQuery(q3);
        System.out.println("select executed");

        String childsname = new String();
        int storycount;
        int ctosee;
        String cstype = new String();
        String targetstype = new String();

        while (r.next()){
         childsname =  r.getString("child");
         storycount =   r.getInt("countfw");
         ///////////////////////////////////////
         //if it is greater than 15; decrease
         ////////////////////////////////////////

        int taken  = 0;
        int btake  = 0;
        int ctake  = 0;
        int ntake  = 0;
        int rtake  = 0;
        int ttake  = 0;

         while (storycount - taken > 15) {
           nextRand = Math.abs(gen.nextInt())% storycount;
           System.out.println(nextRand);
           int totalsofar = 0;
           String q34 = new String ("Select child, stype, tosee from adapt "
           + "where child = '" + childsname +"' ");
           r2 = stmt3.executeQuery(q34);
           notyetfound = true;

           while (r2.next()&& notyetfound){
             ctosee = r2.getInt("tosee");
             totalsofar = totalsofar + ctosee;
```

```
        if (nextRand < totalsofar  && ctosee > 1){
          notyetfound = false;
          targetstype = r2.getString("stype");

         if (targetstype.equals ("b"))  {btake++;}
         if (targetstype.equals ("c"))  {ctake++;}
         if (targetstype.equals ("rs")) {rtake++;}
         if (targetstype.equals ("ts")) {ttake++;}
         if (targetstype.equals ("ns")) {ntake++;}
          taken ++;
        }//end if
      }// end while
    }//end while (storycount > 15)

   if (storycount > 15){

   String adaptQbd = new String (" UPDATE adapt SET tosee = tosee - "  +
   btake + " where child = '" + childsname + "' and stype = 'b'");
    System.out.println(adaptQbd);
    stmt4.executeUpdate(adaptQbd);

   String adaptQcd = new String (" UPDATE adapt SET tosee = tosee - "  +
   ctake + " where child = '" + childsname + "' and stype = 'c'");
    System.out.println(adaptQcd);
    stmt4.executeUpdate(adaptQcd);

   String adaptQnd = new String (" UPDATE adapt SET tosee = tosee - "  +
   ntake + " where child = '" + childsname + "' and stype = 'ns'");
    System.out.println(adaptQnd);
    stmt4.executeUpdate(adaptQnd);

   String adaptQrd = new String (" UPDATE adapt SET tosee = tosee - "  +
   rtake + " where child = '" + childsname + "' and stype = 'rs'");
    System.out.println(adaptQrd);
    stmt4.executeUpdate(adaptQrd);

   String adaptQtd = new String (" UPDATE adapt SET tosee = tosee - "  +
   ttake + " where child = '" + childsname + "' and stype = 'ts'");
    System.out.println(adaptQtd);
    stmt4.executeUpdate(adaptQtd);

  }//if storycount <15

  ////////////////////////////////////////
  //if it is less than 15; increase
  /////////////////////////////////////////
  int added = 0;
  int badd = 0;
  int cadd =0;
  int nadd = 0;
  int radd = 0;
  int tadd = 0;

  while  (storycount + added < 15) {
    nextRand = Math.abs(gen.nextInt())% storycount;
```

```
        System.out.println(nextRand);
        int totalsofar = 0;
        String q35 = new String ("Select child, stype, tosee from adapt "
        + "where child = '" + childsname +"' ");
        r2 = stmt3.executeQuery(q35);

        notyetfound = true;
        while (r2.next()&& notyetfound){
          ctosee = r2.getInt("tosee");
          totalsofar = totalsofar + ctosee;
          if (nextRand < totalsofar ){
            notyetfound = false;
            targetstype = r2.getString("stype");
           if (targetstype.equals ("b"))  {badd++;}
           if (targetstype.equals ("c"))  {cadd++;}
           if (targetstype.equals ("rs")) {radd++;}
           if (targetstype.equals ("ts")) {tadd++;}
           if (targetstype.equals ("ns")) {nadd++;}

            added ++;
          }//end if
        }//
      }

      if (storycount < 15) {

       String adaptQb = new String (" UPDATE adapt SET tosee = tosee + "  + badd
       + " where child = '" + childsname + "' and stype = 'b'");
        System.out.println(adaptQb);
        stmt4.executeUpdate(adaptQb);

       String adaptQc = new String (" UPDATE adapt SET tosee = tosee + "  + cadd
       + " where child = '" + childsname + "' and stype = 'c'");
        System.out.println(adaptQc);
        stmt4.executeUpdate(adaptQc);

       String adaptQn = new String (" UPDATE adapt SET tosee = tosee + "  + nadd
       + " where child = '" + childsname + "' and stype = 'ns'");
        System.out.println(adaptQn);
        stmt4.executeUpdate(adaptQn);

       String adaptQr = new String (" UPDATE adapt SET tosee = tosee + "  + radd
       + " where child = '" + childsname + "' and stype = 'rs'");
        System.out.println(adaptQr);
        stmt4.executeUpdate(adaptQr);

       String adaptQt = new String (" UPDATE adapt SET tosee = tosee + "  + tadd
       + " where child = '" + childsname + "' and stype = 'ts'");
        System.out.println(adaptQt);
        stmt4.executeUpdate(adaptQt);

      }//if storycount <15
    }//end of  while (r.next())

    System.out.println("finished");
```

TSAdapter2.java

```
  } //end of try block
  catch (java.sql.SQLException e) {
      System.out.println (  "SQL exception at connect " + e);
  } // end catch block
} //end TSAdapter constructor

  public static void main(String[] args) throws Exception {
    TSAdapter2 tsa = new TSAdapter2(Integer.parseInt(args [0]));
    System.in.read();     //stops the standard input window closing
  }  // end main
} //end TSadapter class
```

Database objects

The following database tables and queries required to run the TouchStory, Populate and Adapter programs.

Standard notations are used: underline indicates the primary key, * indicates a foreign key. The <someword> notation indicates an un-named, derived attribute, or a table name to be instantiated.

Table 2 Database objects required by the TouchStory suite of programs

DB object	Type	What is it for?
Child(name, visit, logged, story, isCorrect)	Table	It is the relation that TouchStory logs to
Game (gameId, name, type, storypicsid*, optionpicsid*, pos_correct, pos_blank, seqintype)	Table	t-stories which use stored images
Storypics (storypicsid, picsname, blank, count-story-pics, pic1, …, pic9)	Table	Images for the panels
Optionpics (optionpicsid, optionsname, count-option-pics,pic1, …, pic9)	Table	Images for the distracters
DrawnStories (name, shape, back, fore, length,shape01,back01, fore01, posn01, shape02, back02, fore02, posn02, posn_correct, posn_blank, blank, type, seqintype)	Table	Data for t-stories which use software drawn images
<Participant's name> (name) e.g. Megan (name)	Table	One such table for each participant contains the names of the t-stories to be used for this participant when TouchStory is run
Adapt(child, stype, tosee)	Table	For each participant the number of t-stories from each proto-narrative category he or she is to be shown
Schedule(visit, stype, name, order)	Table	For each visit and each proto-narrative category the t-stories which may be offered. 'Order' shows which t-stories should be offered to participants who arfe to see fewer than all of them.
Map (isCorrect, correct)	Table	Maps the Boolean attribute isCorrect to the number 0/1

DB object	Type	What is it for?
Log2 (name, visit, logged, story, stype, correct) populated from INSERT INTO log2 (name, visit, logged, story, stype, correct) SELECT child.name, child.visit, child.logged, child.story, Stories.stype, map.correct FROM (child INNER JOIN map ON child.isCorrect=map.isCorrect) INNER JOIN Stories ON child.story=Stories.storyname ORDER BY child.name, child.visit;	Table	As Child except stype (the proto-narrative category of the t-story)is included Boolean outcome is mapped to 0/1 for ease of processing
AdaptQQ (name,stype,visit,outcome) SELECT log2.name, log2.stype, visit, Sum(log2.correct)/Count(log2.correct) AS outcome FROM log2 GROUP BY log2.name, visit, log2.stype;	Query	For each participant / visit / proto-narrative category, the number of t-stories answered correctly as a proortion of those the participant answered
toInc(name,stype,<count>) SELECT adaptQQ.name, adaptQQ.stype, count(outcome) FROM adaptQQ WHERE outcome >= 0.5 GROUP BY adaptQQ.name, adaptQQ.stype HAVING count(outcome)>1;	Query	For each participant the proto-narrative categories to be increased following adaptation (note there is a calling order constraint on toInc and toDec) see TSAdapter2.java
toDec(name,stype,<count>) SELECT adaptQQ.name, adaptQQ.stype, count(outcome) FROM adaptQQ WHERE outcome=1 GROUP BY adaptQQ.name, adaptQQ.stype HAVING count(outcome)>1;	Query	For each participant the proto-narrative categories to be decreased following adaptation (note there is a calling order constraint on toInc and toDec) see TSAdapter2.java

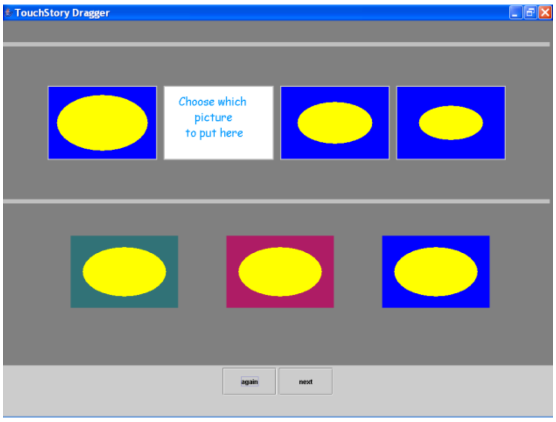
APPENDIX G: T-STORIES

This appendix presents screenshots of the t-stories created for trial 2 and trial 3, organised by proto-narrative category

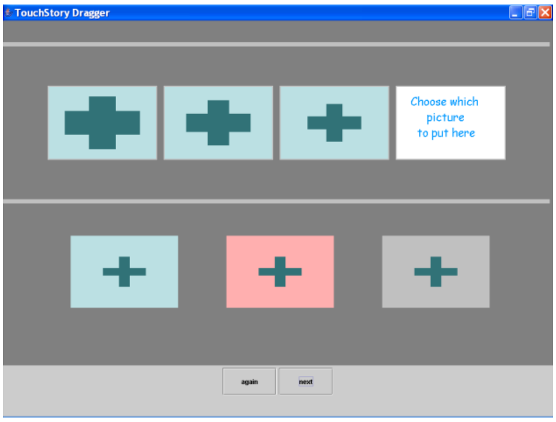
T-stories from proto-narrative category: background

T-stories of proto-narrative category BACKGROUND

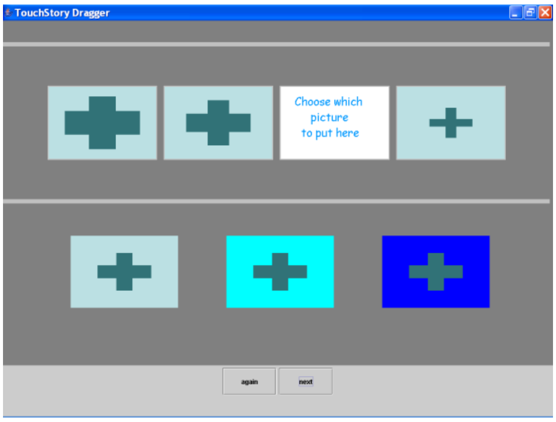
b1: BACKGROUND



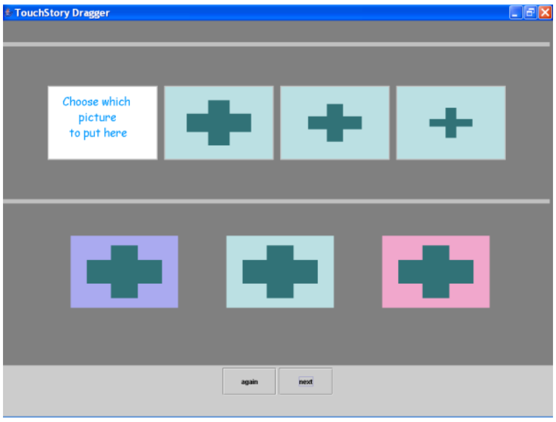
b6: BACKGROUND



b4: BACKGROUND

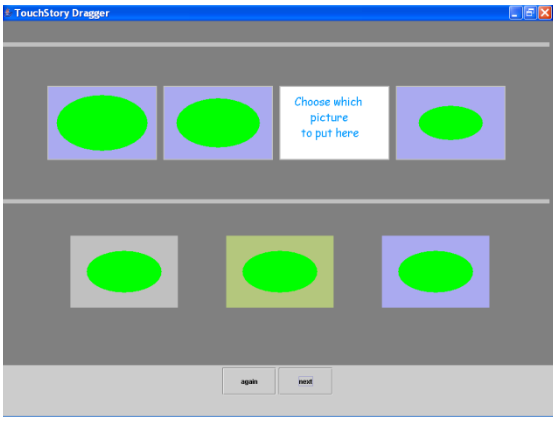


b3: BACKGROUND

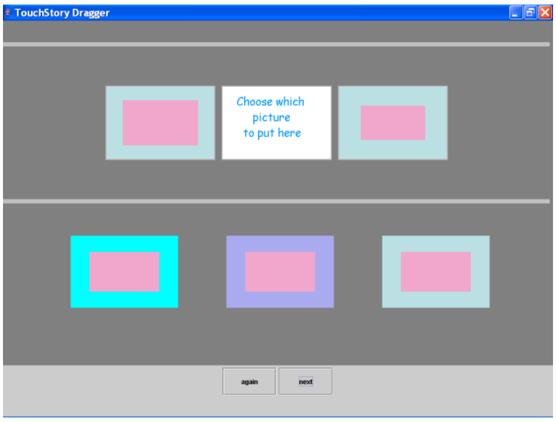


T-stories of proto-narrative category BACKGROUND

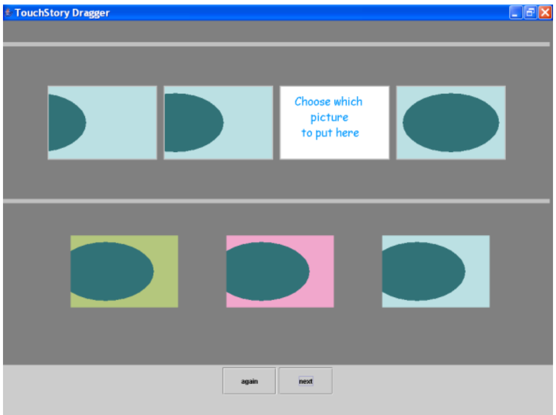
b2: BACKGROUND



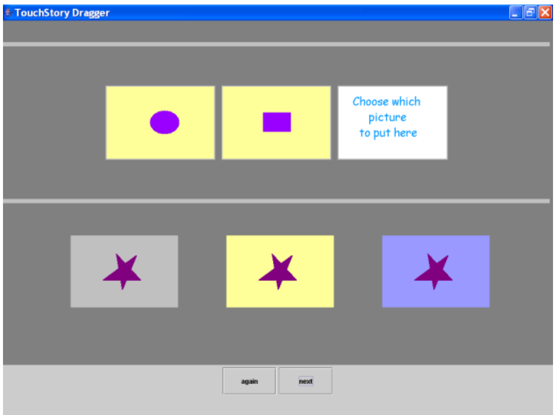
b7: BACKGROUND



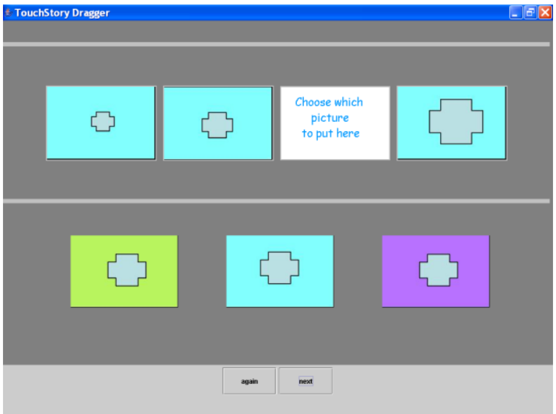
b5: BACKGROUND



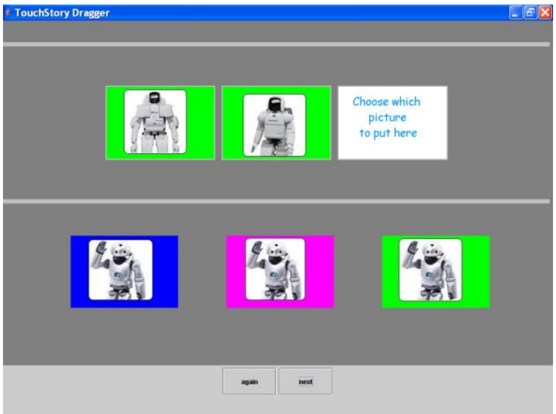
StarB: BACKGROUND



cross3: BACKGROUND

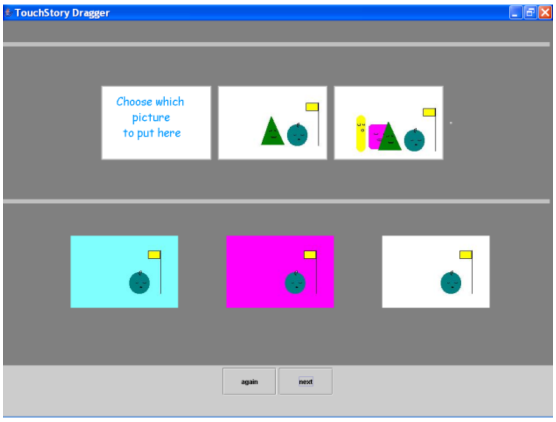


robs: BACKGROUND

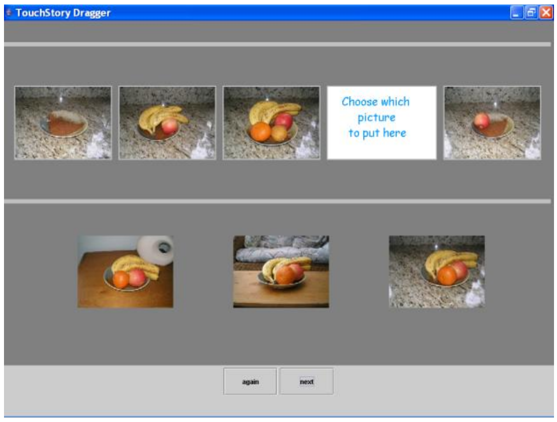


T-stories of proto-narrative category BACKGROUND

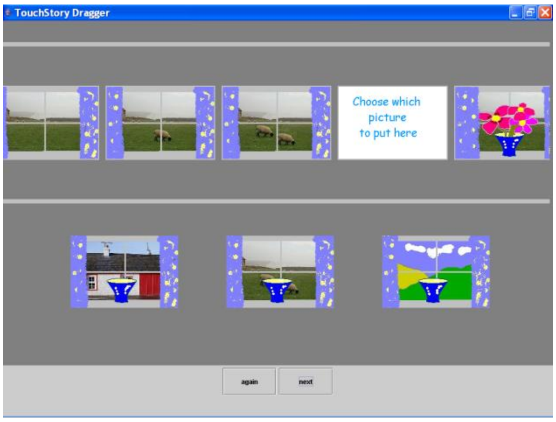
BB: BACKGROUND



FB: BACKGROUND



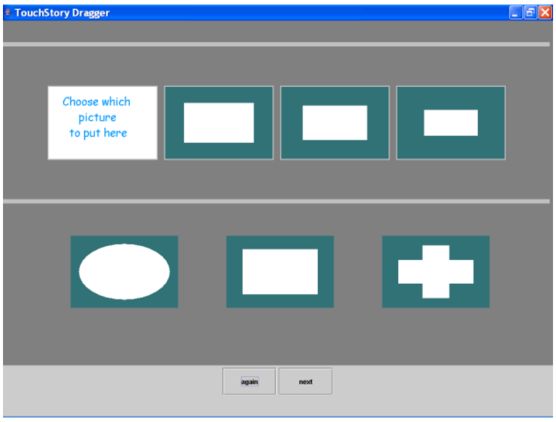
sheep: BACKGROUND



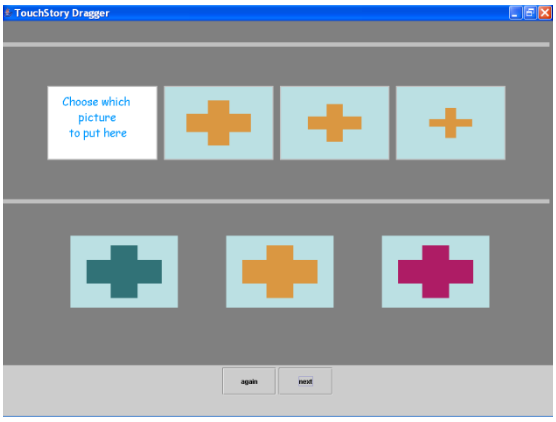
T-stories from proto-narrative category: character

T-stories of proto-narrative category CHARACTER

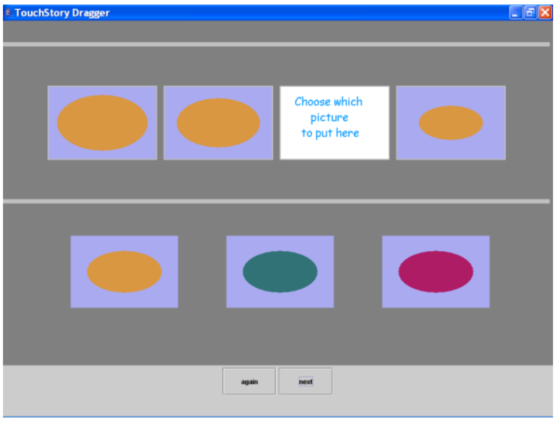
s3: CHARACTER



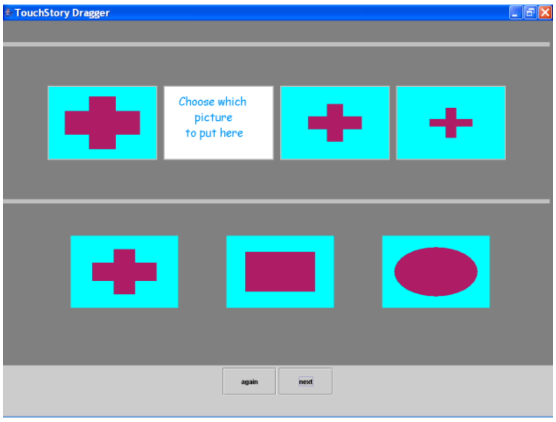
c1: CHARACTER



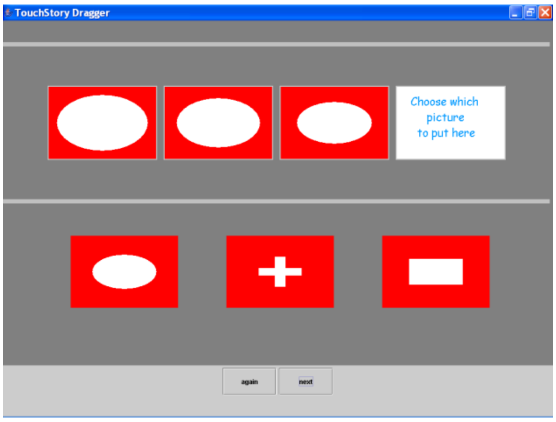
c2: CHARACTER



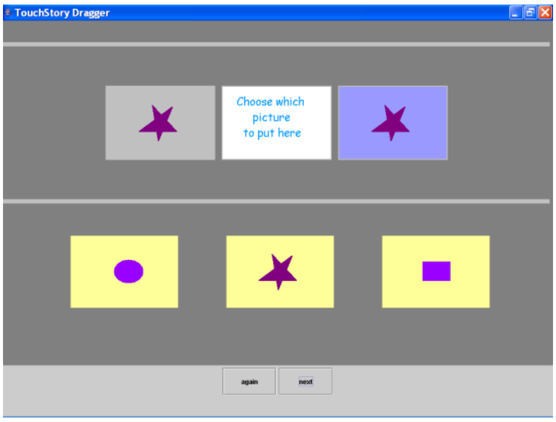
s1: CHARACTER



s2: CHARACTER

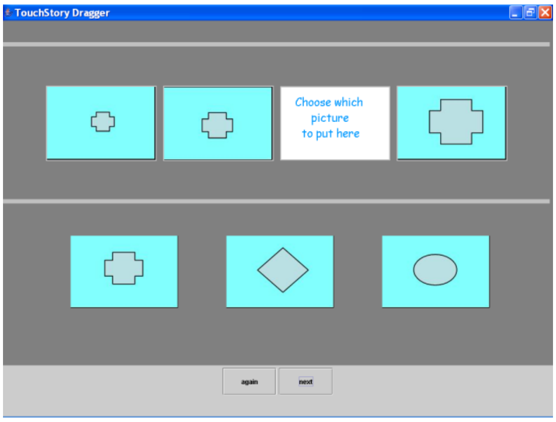


purplestar: CHARACTER

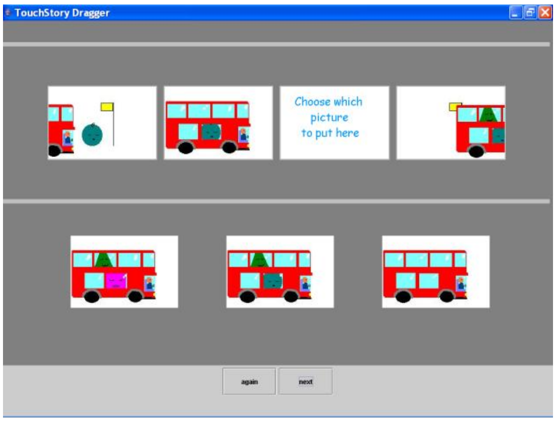


T-stories of proto-narrative category CHARACTER

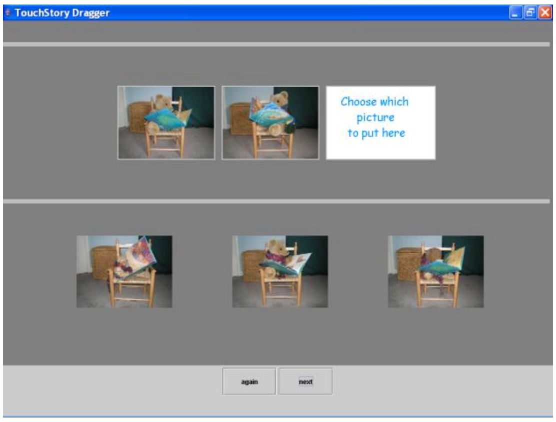
cross1: CHARACTER



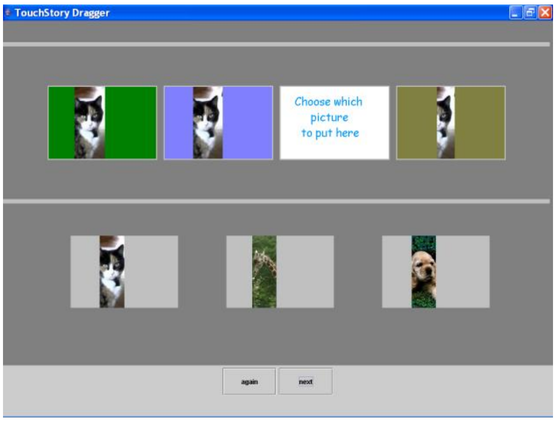
C: CHARACTER



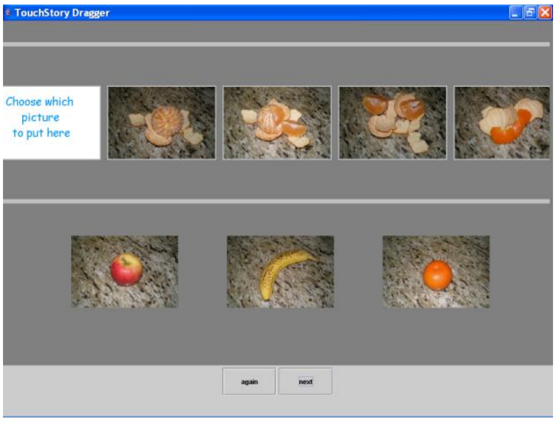
TedStory: CHARACTER



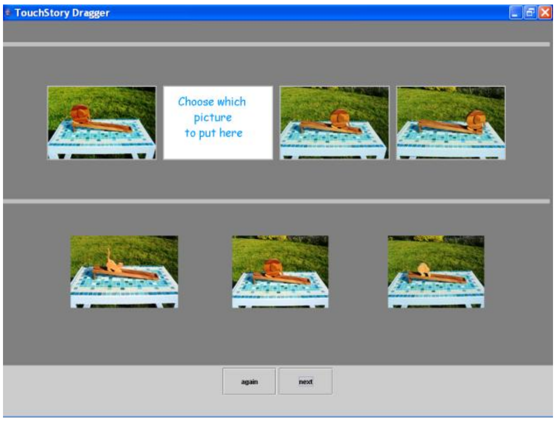
sal: CHARACTER



orange: CHARACTER



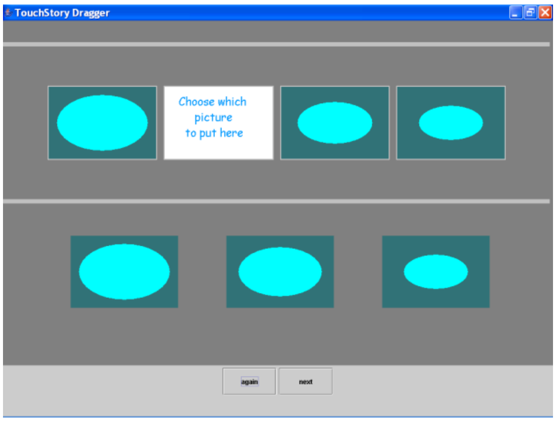
eleslide: CHARACTER



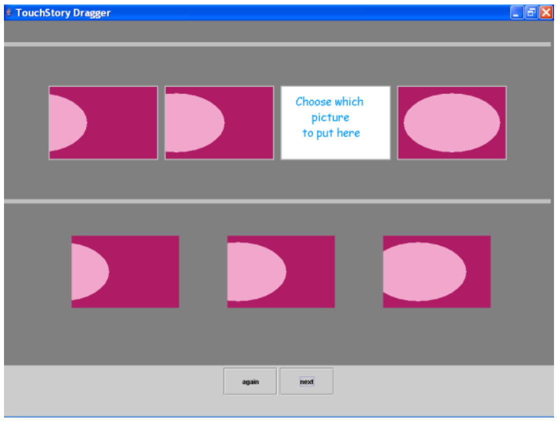
T-stories from proto-narrative category: reversible sequence

T-stories of proto-narrative category REVERSIBLE SEQUENCE

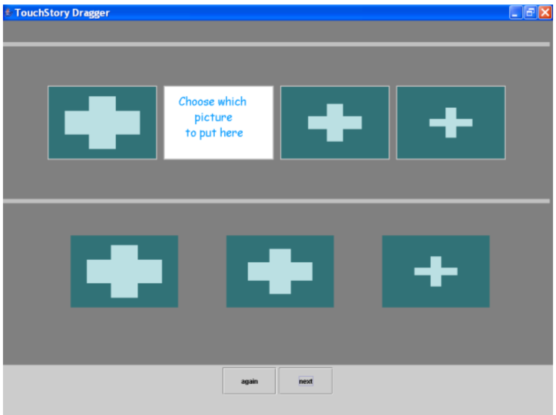
o9: REVERSIBLE



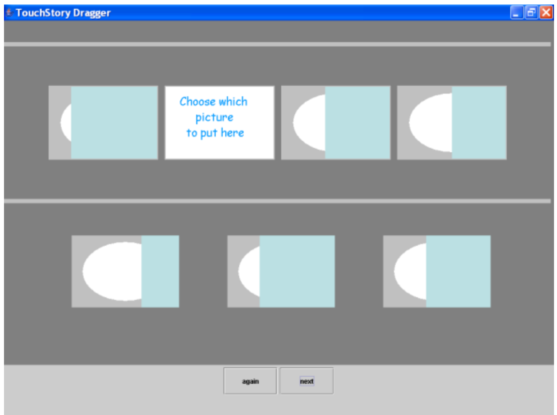
o2: REVERSIBLE



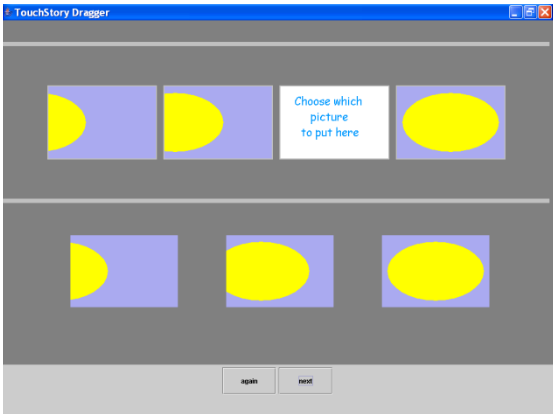
o1: REVERSIBLE



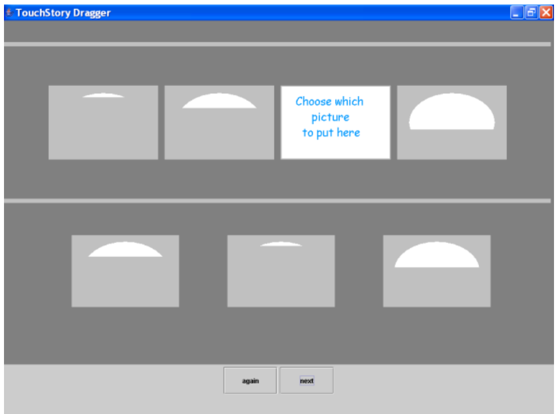
o5a: REVERSIBLE



o3: REVERSIBLE

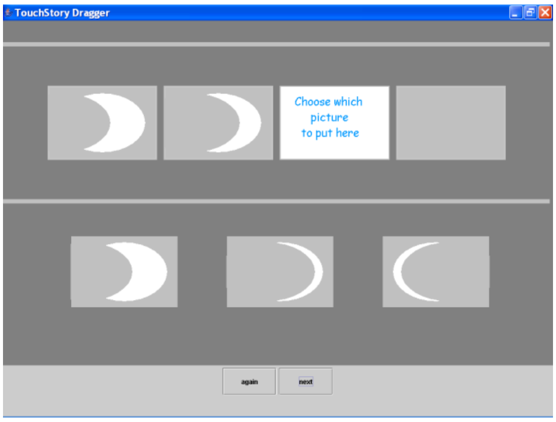


egg1a: REVERSIBLE

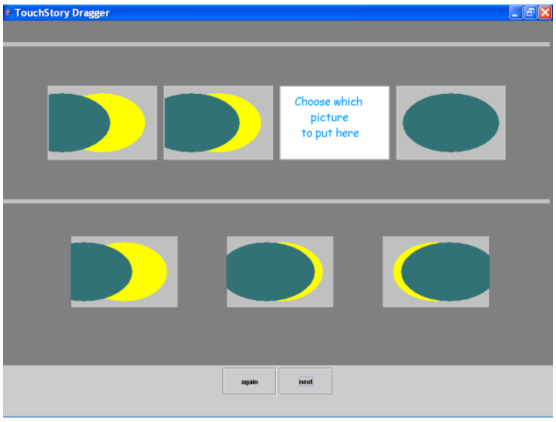


T-stories of proto-narrative category REVERSIBLE SEQUENCE

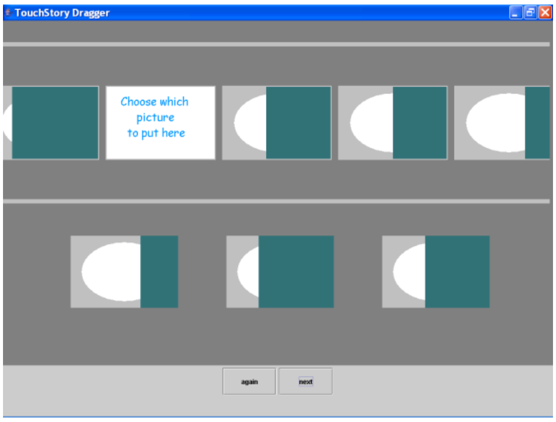
o6a: REVERSIBLE



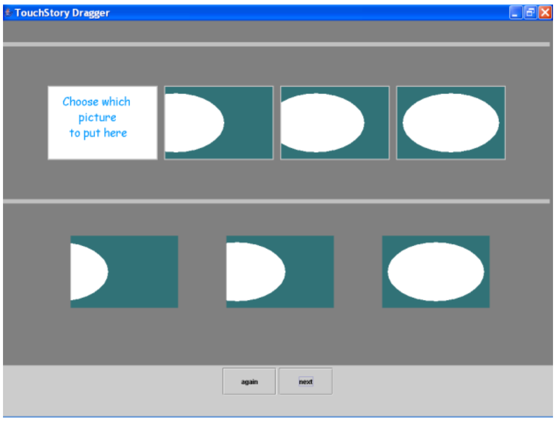
o6: REVERSIBLE



o5: REVERSIBLE

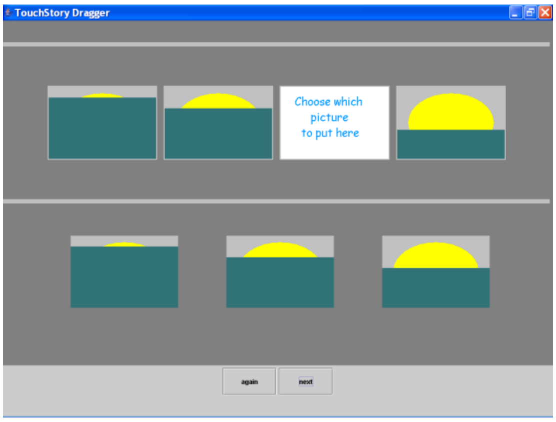


o4: REVERSIBLE



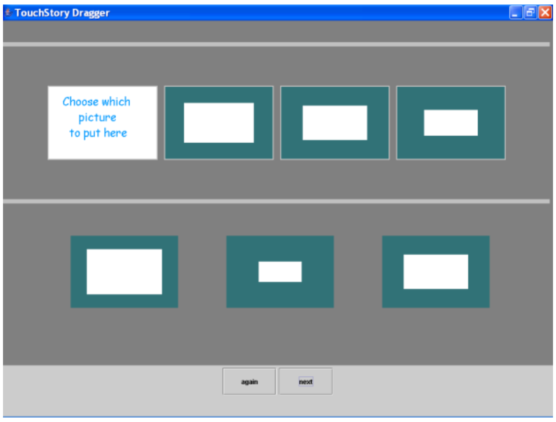
o2a: REVERSIBLE

egg1: REVERSIBLE

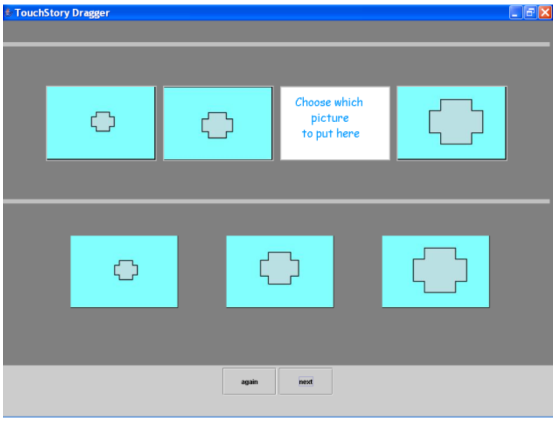


T-stories of proto-narrative category REVERSIBLE SEQUENCE

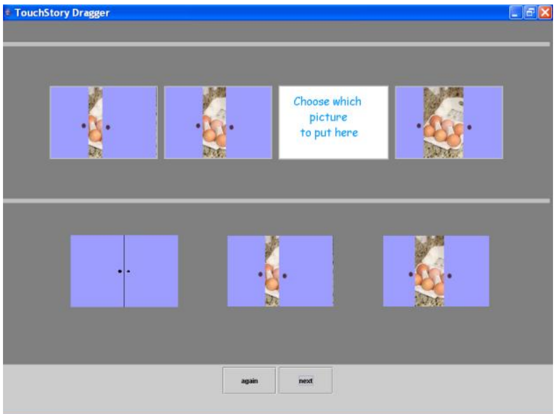
seq2: REVERSIBLE



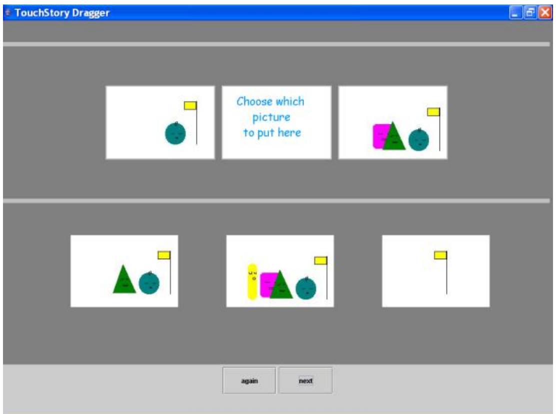
cross2: REVERSIBLE



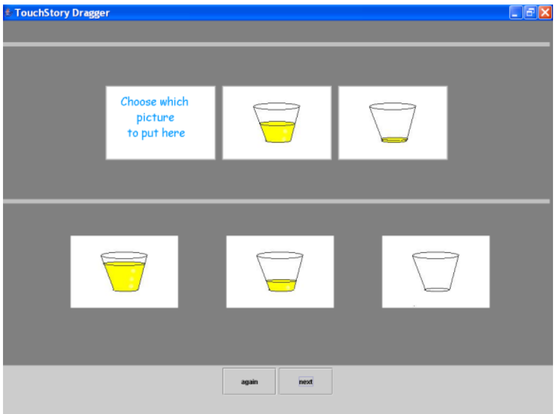
egg2a: REVERSIBLE



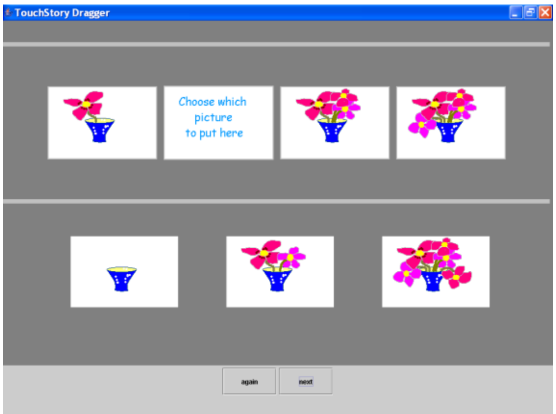
Q: REVERSIBLE



juice: REVERSIBLE

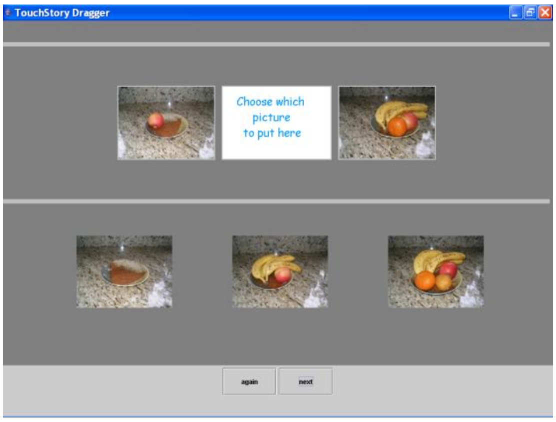


bluevase: REVERSIBLE

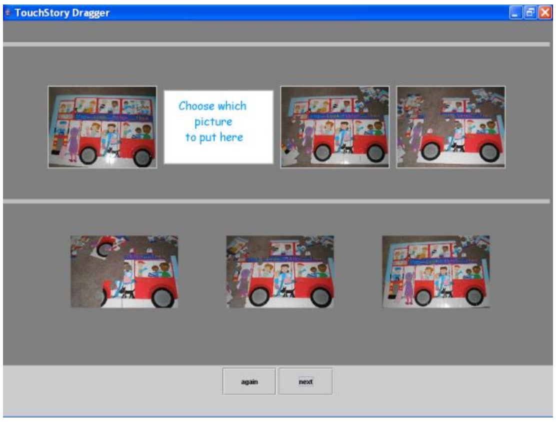


T-stories of proto-narrative category REVERSIBLE SEQUENCE

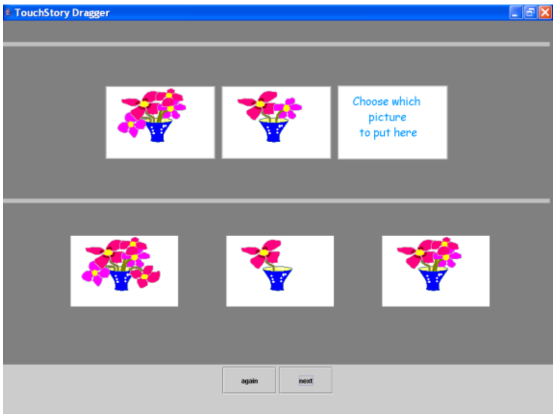
NFB: REVERSIBLE



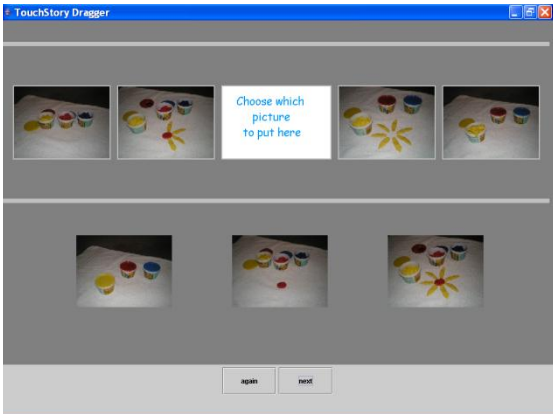
bus2: REVERSIBLE



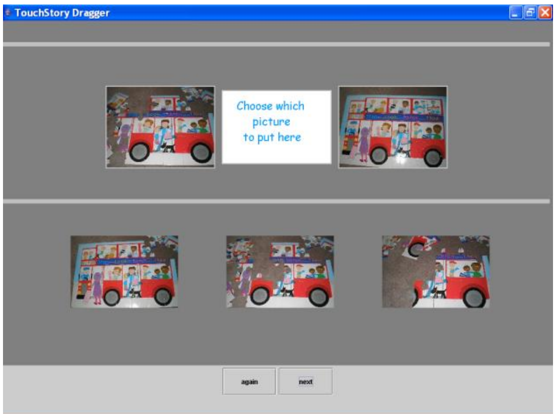
bvn:REVERSIBLE



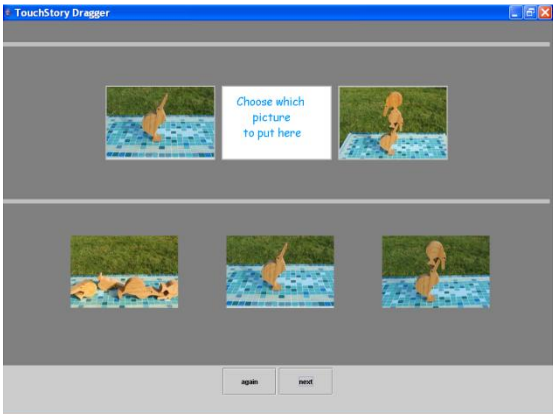
doh: REVERSIBLE



bus: REVERSIBLE



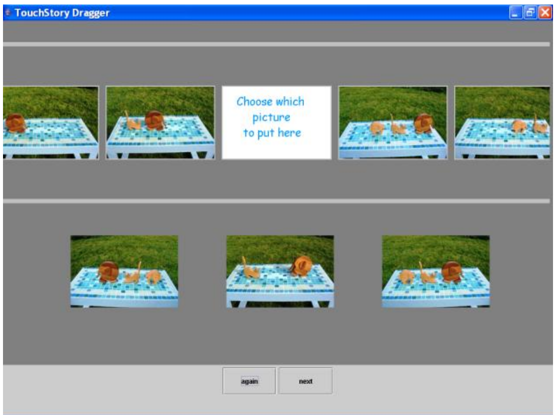
kiwi1: REVERSIBLE



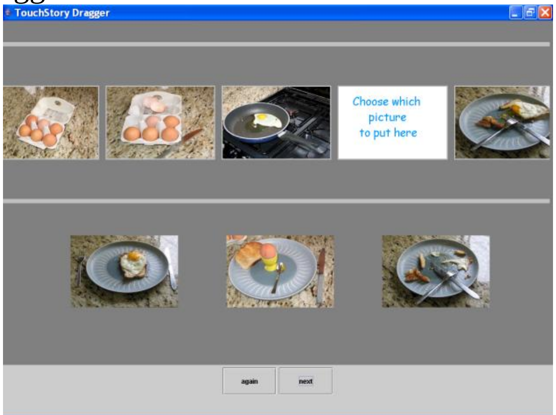
T-stories from proto-narrative category: temporal sequence

T-stories of proto-narrative category TEMPORAL SEQUENCE

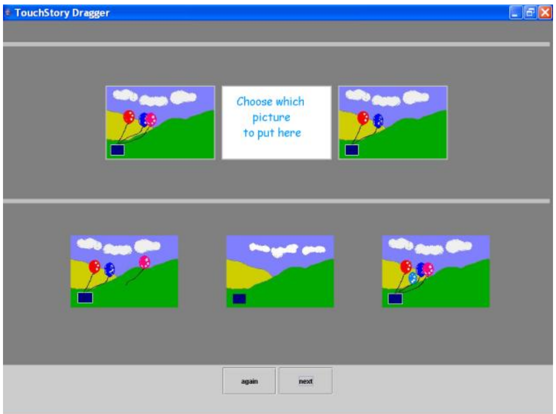
elewalk: TEMPORAL



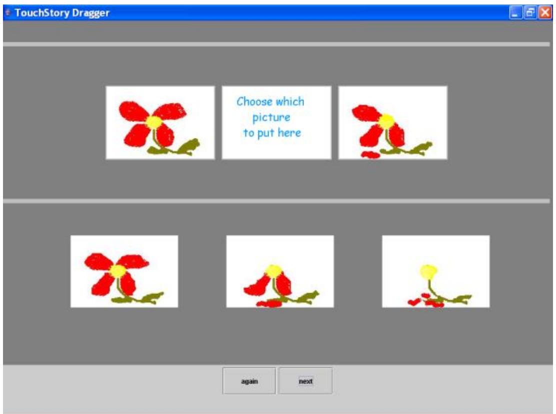
egg3: TEMPORAL



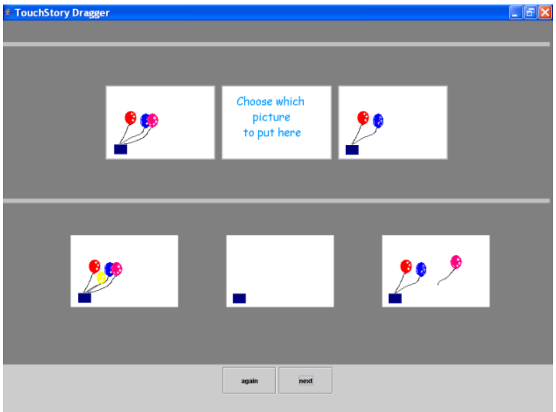
newballoon: TEMPORAL



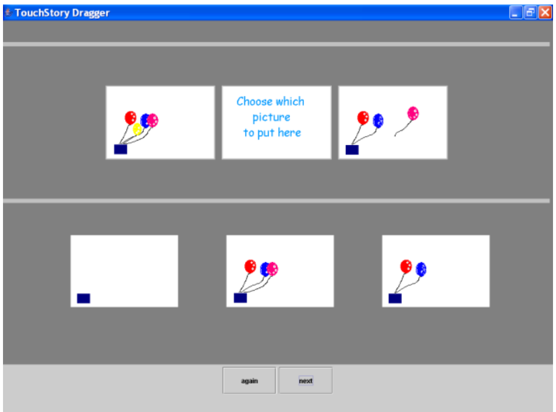
flower: TEMPORAL



balloons: TEMPORAL

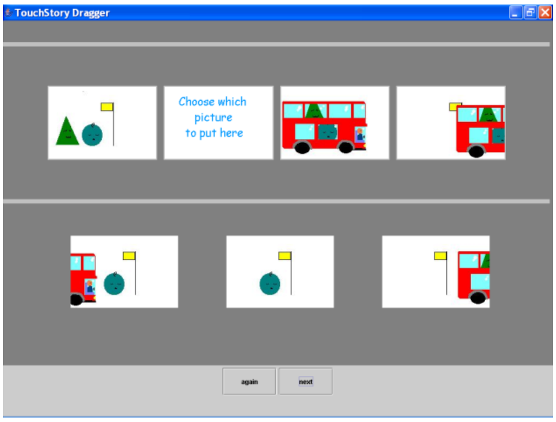


bal2: TEMPORAL

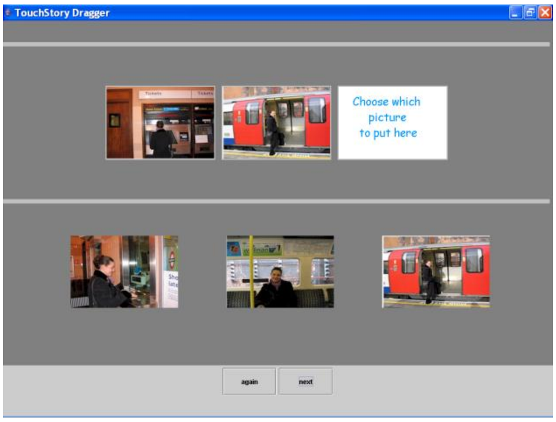


T-stories of proto-narrative category TEMPORAL SEQUENCE

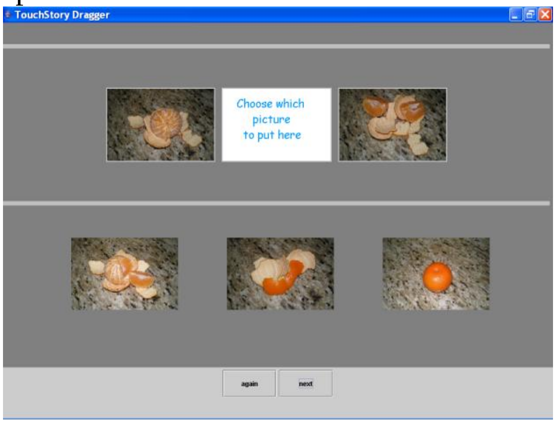
B: TEMPORAL



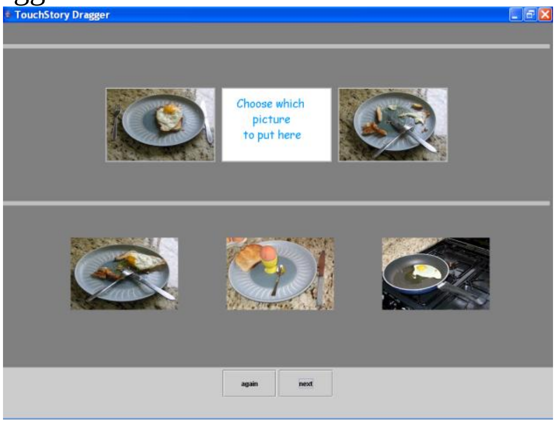
tick: TEMPORAL



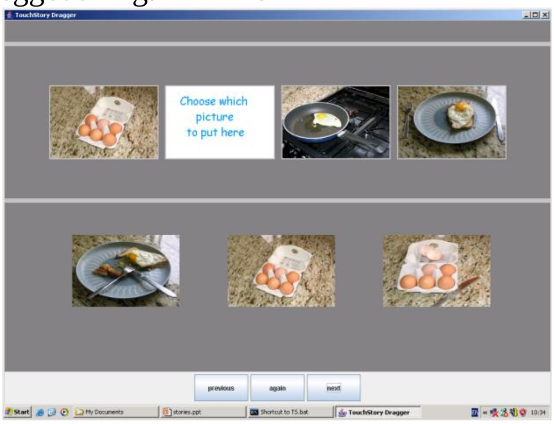
opeel: TEMPORAL



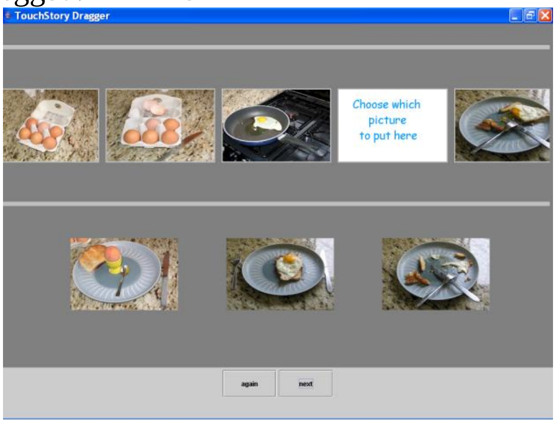
eggmeal: TEMPORAL



eggcooking: TEMPORAL

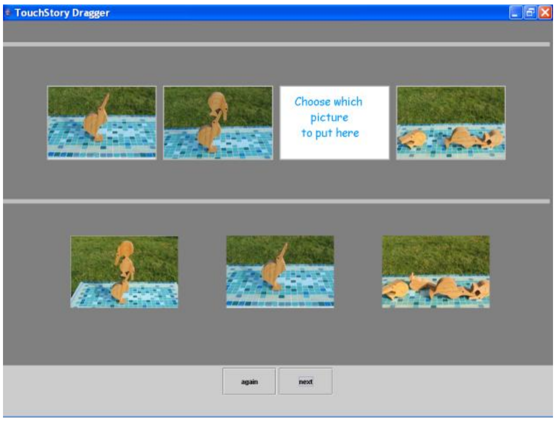


egg3a: TEMPORAL



T-stories of proto-narrative category TEMPORAL SEQUENCE

kiwi2: TEMPORAL

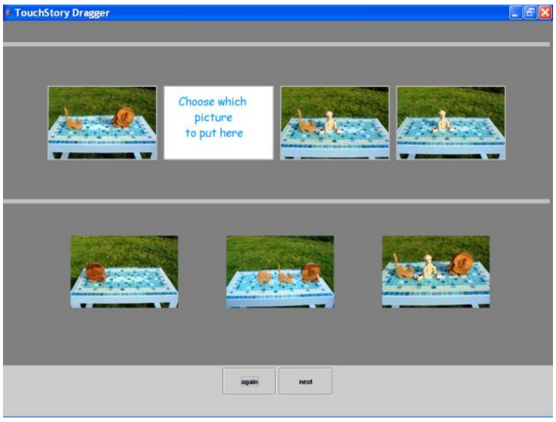


T-stories from proto-narrative category: narrative sequence

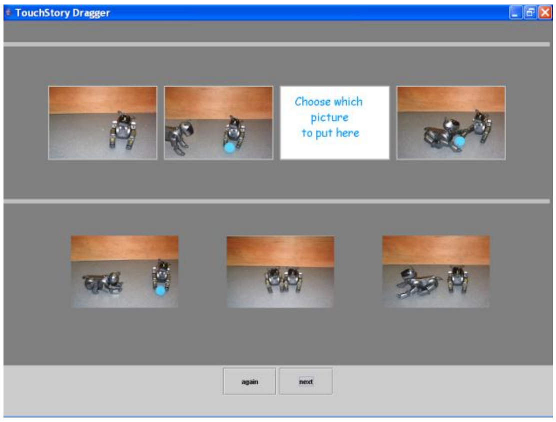
This section shows t-stories created by the author. T-stories *Hairy*, *Sit*, *Beach*, *Hair_c*, *Rain*, *Hair*, and *shortbeach* were based on published sources are not shown here

T-stories from proto-narrative category NARRATIVE SEQUENCE

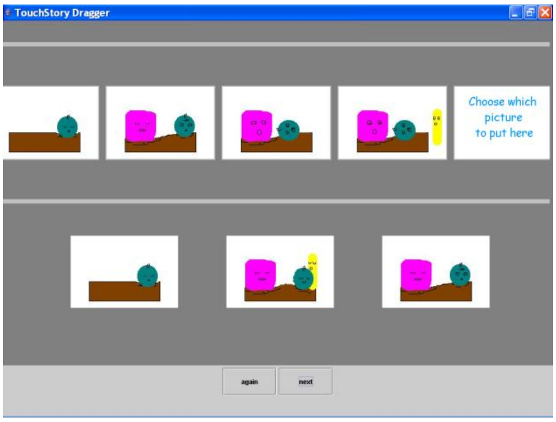
Farmer:NARRATIVE



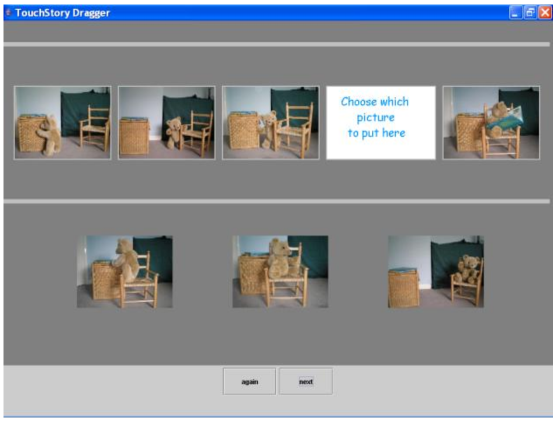
d1:NARRATIVE



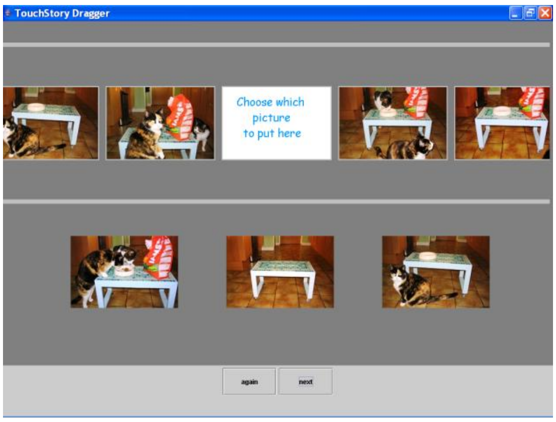
set:NARRATIVE



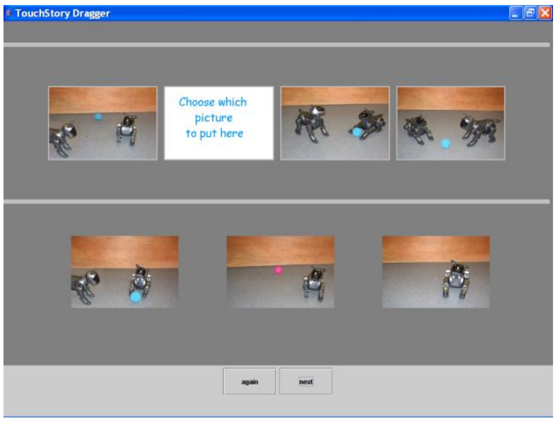
Ted:NARRATIVE



cats:NARRATIVE



dogs:NARRATIVE



Rollout of t-stories

Table Rollout shows the rollout of t-stories throughout trial 3. An X in a cell means that the t-story was used for sessions in that visit. Shading means that the t-story was available to be used to provide additional practice where it was indicated by the adaptive function; thus an X in a shaded box means that the t-story was answered by at least one child during that visit.

It can be seen that both visit 2 and visit 19 replicate visit 1, and visit 20 used new t-stories.

Table Rollout: the rollout of t-stories throughout trial 3. T-stories marked are taken from published sources and are not illustrated here*

		visit																			
stype	**story**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
b	b2	X	X								X	X	X	X						X	
b	b3	X	X	X	X							X								X	
b	sheep			X	X	X	X		X												
b	starB			X	X	X	X	X	X	X	X	X									
b	cross3					X	X	X	X	X	X										
b	b5							X	X	X	X	X	X	X							
b	robs									X	X	X	X	X	X	X	X				
b	b7											X	X	X	X	X	X	X	X		
b	FB															X	X	X	X		
b	BB																	X	X		
b	b4																				X
b	b6																				X
c	c2	X	X								X	X	X	X	X	X	X	X	X	X	
c	s3	X	X	X	X															X	
c	orange			X	X	X	X	X	X	X	X	X					X				
c	purplestar			X	X	X	X		X						X	X					
c	c1					X	X	X	X												
c	cross1					X	X	X	X	X	X						X	X	X		
c	s1							X	X	X	X	X	X	X	X						
c	eleslide									X	X	X	X	X	X	X	X	X	X		
c	sal											X	X	X	X	X	X	X	X		
c	Tedstory															X	X	X	X		
c	C																	X	X		
c	c2a																				X
c	s2a																				X
ns	Hairy*	X	X										X	X	X		X	X	X	X	
ns	Sit*	X	X	X	X	X	X		X		X	X	X	X	X		X			X	
ns	Beach*			X	X	X	X	X	X	X	X	X									
ns	Hair_c*					X	X	X	X	X	X		X	X	X		X	X	X		
ns	Rain*							X	X	X	X	X	X	X	X						
ns	cats								X	X	X	X	X	X	X	X	X	X	X		
ns	dogs											X	X	X	X	X	X	X	X		
ns	Ted															X	X	X	X		
ns	set																	X	X		
ns	bvn																				X
ns	Hair*																				X
ns	shortbeach*																				X
rs	bluevase	X	X	X	X												X	X	X	X	
rs	bus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
rs	egg1a	X	X	X	X															X	

		visit																			
stype	**story**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
rs	egg2a	X	X	X	X	X	X		X				X	X	X	X				X	
rs	o3	X	X	X	X															X	
rs	o6a					X	X	X	X	X	X										
rs	cross2							X	X	X	X	X	X	X	X		X		X		
rs	kiwi1									X	X	X	X	X	X	X					
rs	o2										X	X	X	X	X	X					
rs	o5											X	X	X	X	X	X	X	X		
rs	juice													X	X	X	X	X	X		
rs	NFB															X	X	X	X		
rs	Q																	X	X		
rs	bus2																				X
rs	egg2																				X
rs	o2a																				X
rs	o5																				X
ts	balloons	X	X										X	X	X	X				X	
ts	eggcooking	X	X	X	X	X	X		X				X	X	X	X				X	
ts	tick	X	X	X	X							X					X	X	X	X	
ts	newballoon			X	X	X	X	X	X			X					X	X	X		
ts	kiwi2					X	X	X	X	X	X	X	X	X	X	X					
ts	egg3a							X	X	X	X		X	X	X		X	X	X		
ts	opeel									X	X	X	X	X	X	X	X		X		
ts	eggmeal											X	X	X	X	X	X	X	X		
ts	flower													X	X	X	X	X	X		
ts	doh															X	X	X	X		
ts	B																	X	X		
ts	bal2																				X
ts	Bnew																				X
ts	egg3																				X