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Design and evaluation of a CAL system to support communication development in children with autism

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Design and evaluation of a CAL system to support communication development in children with autism

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Abstract

The prevalence of autism in children in the United Kingdom is estimated as one in one hundred (Department of Health, 2012), with higher levels reported in some countries (Srivastava, 2013). These children experience significant problems with the development of language and communication skills. A symbol-based communication system called Picture Exchange Communication System (PECS) is widely used to address this issue and evidence indicates this approach can be effective when administered by trained professionals (Preston and Carter, 2009).

Technology appears to offer an alternative way of encouraging non-verbal children with autism to use symbol-based communication to improve social interaction and communication. Therefore, the purpose of the research was to answer the following research questions:

1. Can a Computer Assisted Learning (CAL) system be designed and implemented to support PECS pedagogy for the purpose of improving symbol communication and social interaction in non-verbal children with autism?

2. To what extent could such a system improve the communication and social interaction skills of non-verbal children with autism?

The investigation comprised three stages. In Stage 1, a prototype system was developed incorporating a 'virtual tutor' and an RFID-based (radio frequency identification) user interface to support physical symbol selection and placement.

In Stage 2, a pilot study focused on classroom learning experiences of eight children using CAPE Version 1. Results provided 'proof of concept' and indicated

that non-verbal children with autism learned to interact effectively with CAPE. Participants achieved more appropriate symbol selections when a virtual tutor used a synthetic voice compared to a natural voice alternative. Outcomes from the pilot informed the development of a CAPE Version 2.

Stage 3 comprised a four-week classroom study involving five non-verbal children with autism. Children, using CAPE Version 2, answered numeracy questions using graphic symbols. Interviews from supporting teachers provided a degree of triangulation with investigator observations and teacher interviews. Stage 3 results suggest that four participants developed their communication skills, one child learned to count, three children improved basic numeracy skills and two children used speech using CAPE version 2, supported by a virtual tutor and a human teacher. This research suggests that non-verbal children with autism can engage positively and productively with PECS using the CAPE approach.

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Dedications

I dedicate this thesis to my wife Sharon who has given so much love and support to me over the years, my mother who sadly passed away during the final stages of writing this thesis and my son Jacob whose courage, determination and hard work to overcome autism inspired my research.

Paul John Herring

Publications arising from this thesis

Publications

Herring, P. (2009) 'Can Computer Assisted Learning technology help autistic children to communicate?', *SLD (Severe Learning Difficulties) Experience*, BILD (British Institute of Learning Disabilities), Issue 53, pp. 23 – 28.

Herring, P., Sheehy, K. and Jones, R. (2009) 'Investigating a 'virtual tutor' approach for improving the communication skills of children with autism', *ALT-C 2009 "In Dreams Begins Responsibility": Choice, Evidence and Change*, 8-10 Sep 2009, Manchester, UK, Association for Learning Technology.

Herring, P., Sheehy, K., Jones, R. and Kear, K. (2010) 'Designing a virtual teacher for non-verbal children with autism: Pedagogical affordances and the influence of teacher voice', *4th International Wireless Ready Symposium, Digital Asia: Language\Technology & Community*, JALT, 19 Feb 2010, Nagoya, Japan.

Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1. Introduction

Autism is a neuro-developmental disorder that has seen an alarming increase over the last thirty years and has been estimated to affect 1 in 100 children in the United Kingdom (Department of Health, 2012), with higher levels reported in some other countries (Srivastava, 2013). Children with autism have impairments in social communication, social imagination and social relationships, referred to as the triad of impairments (Wing, 2002, p. 25). These impairments can seriously affect child development in the early years causing the individual to be isolated from society, with attendant behavioural difficulties.

Autism is usually diagnosed at around three years of age. Research suggests that early communication interventions can reduce inappropriate behaviours, often associated with frustration and distress, exhibited by young children with communication deficits (Cafiero, 2008). In addition, early intervention can provide long-term improvements to a child's ability to integrate with society (Wetherby and Woods, 2006). Communication support for non-verbal children with autism is provided by a symbol-based communication method called the Picture Exchange Communication System (PECS). PECS is widely used to help non-verbal children with autism to express their needs and desires to others. However, PECS requires trained professionals to teach communication using graphic symbols.

PECS graphic symbols are used by children with autism as a way of making a non-verbal request for an object or activity they desire. In this thesis, graphic symbols depicting objects or digits are described collectively as 'symbols'.

However, where a distinction is required the terms 'digit symbol' and 'picture symbol' will also be used.

In recent years, an increasing number of computer-based teaching tools have been developed to overcome communication impairments of affected children. The literature suggests that technology approaches are very popular with children with autism (Moore and Calvert, 2000; Shane & Albert, 2008; Ferguson et al., 2012, p. 249). In addition, computer-based interventions can promote social interaction and in some cases speech (Checkley et al., 2010).

RFID-enabled physical symbols have been used as a primary user input for a Speech Generating Device to model PECS symbol exchange with a human partner (Boesch et al., 2013). However, most computer-based symbol communication interventions have relied on onscreen symbols and touch-screen or mouse-based inputs as the primary user interface (see Koul & Schlosser, 2004; Bird, 2009; Lorah et al., 2013).

A number of computer-based approaches have used onscreen animated characters (or avatars) to promote social interaction (Leopold, 2007; Tartaro & Cassell, 2008) and to act as a virtual tutor (Cole, 2003; Massaro & Bosseler et al, 2003). The inclusion of a virtual tutor-led intervention may offer a number of advantages compared to those of human interaction. For example, computer-based interventions that incorporate virtual tutor-led PECS lessons may allow adults or teaching staff with little knowledge of PECS pedagogy to help non-verbal children with autism to improve symbol-based communication skills. Although research studies have highlighted the potential of RFID-enabled symbols for user input (Boesch et al., 2013) and virtual tutor-led lessons for children with autism (Cole, 2003; Massaro & Bosseler l, 2003) researchers have not considered how to

implement the PECS symbol exchange with an on-screen, computer generated virtual tutor using RFID-enabled physical symbols as the primary user input.

1.2. Focus of the research

The research presented here explores whether a computer-based, virtual tutor-led teaching system could support the communication needs of children with autism who have limited or no usable speech. This system was designed to use physical symbols with the same look and feel as PECS symbols and to follow the PECS pedagogy.

The research considered how children with autism, with limited or no verbal communication could be encouraged to improve numeracy skills using symbol-based communication with a computer-based teaching environment that exploits physical symbol user input. If children with autism are able to interact with a PECS-based computer system using physical symbols, in conjunction with child-teacher collaboration on learning tasks, it could be possible to influence a child's use of joint attention and social interaction.

The research aimed to design, implement and trial a CAL-based PECS system, termed Computer Assisted Picture Exchange (CAPE) to determine its efficacy in teaching symbol-based communication to young children with autism who also had severely limited communication skills. To investigate this issue, a three-stage research approach was adopted.

In Stage one, an initial PECS-based CAL prototype called CAPE Simulator, was designed and built. CAPE Simulator was designed to test possible user input functionality. Results from testing functionality in CAPE Simulator was used to design and implement an improved CAPE system called CAPE V1 which was

based upon good practices obtained from the literature. A key aspect of the initial design of CAPE V1 was the investigation and development of an appropriate user input method. A number of input methods used in current system designs were considered and a design based on Radio Frequency Identification (RFID) technology was chosen as an appropriate way of providing symbol-based user input. CAPE V1 functionality was tested with the help of a child with autism, who was able to speak. Results from the literature provided useful design considerations for technology for children with autism and this was combined with user testing which informed the development and improvement of the CAPE V1 prototype system.

In Stage two, a pilot study was conducted with non-verbal children with autism between the ages of 6.4 and 8.5 years (decimal) to test CAPE V1 as a 'proof of concept'. The literature suggested that the virtual tutor representation and particularly the voice type would be a key influence on the way participants interact with CAPE. This issue of voice type was investigated during the pilot study. Teachers who worked routinely with the children continued to work with the children. Results from this study were used to inform the development of the improved CAPE V2 teaching environment in Stage 3.

In Stage 3 five children between the ages of 9.2 and 10.3 years took part in a four-week classroom investigative study. The aim of the study was to investigate how CAPE could teach non-verbal children with autism to complete numeracy tasks using symbol communication, based on the PECS pedagogy. During this stage, five members of the host school's teaching staff supported the study. Input from daily interviews with teaching staff provided a degree of triangulation with investigator observations and system measurements. Results from these data

helped the researcher to answer research questions designed to assess if a CAL could be used and the effectiveness of CAPE as a PECS-based symbol communication approach, discussed next.

1.3. Research questions

The PECS intervention used to develop communication ability is widely established (Flippin, Reszka, & Watson, 2010) and effective (Lerna et al., 2012), but being dependent upon teacher interactions it is not able to benefit from potential developments that might be possible in a computer aided learning environment. This research sets out to explore the options that might exist for using technology as an alternative to teacher-led PECS approach.

This research had two objectives; the first objective was to investigate a Computer Assisted Learning approach to see if it could be used to improve symbol-based communication and social interaction skills for children with autism who had limited or no functional speech (described here as 'non-verbal'). The development of a PECS-based CAL system to help these children to communicate using symbols would be influenced by the literature. The following question characterises this objective:

> Can a Computer Assisted Learning (CAL) system be designed and implemented to support PECS pedagogy for the purpose of improving symbol communication and social interaction in non-verbal children with autism?

The second objective of the research was to adapt and evaluate a PECS, symbol-based CAL environment. The system would then be used to understand the factors that influence a participant's ability to engage in verbal and non-verbal

communication and social interaction with others, using a CAL system offering a PECS-based learning environment. The following question characterises this objective:

> To what extent could such a system improve the communication and social interaction skills of non-verbal children with autism?

The overall focus of the research was to complement established interventions like PECS, rather than to replace tried and tested interventions.

1.4. Research context and approach

The context of this research was the increase in the number of children being diagnosed with autism. Children diagnosed with autism will typically experience a delay of usable speech and an impairment in communication. A lack of an effective communication method has a profound impact on an individual's emotional and educational development.

Communication interventions like PECS typically require trained professionals to teach this approach and can be very resource intensive. The literature suggests that computer-based approaches are very motivating for children with autism (Parsons & Cobb, 2012; Bauminger-Zviely et al., 2013). CAL approaches have been used as communication interventions for people with language impairment (Koul & Schlosser, 2004; Checkley et al., 2010). RFID-enabled symbols have been used as a user input (Boesch et al. 2012) for Speech Generating Device (SGD) to help children communicate with a teacher. However, most conventional approaches still use traditional input methods like touch screen, keyboard and mouse or buttons to help participants to interact with the system. Conventional methods are adequate as a way of interacting with a computer system but they do

not accurately model physical symbol exchange that is a key component of the PECS pedagogy.

Research has shown that teaching lessons using a computer generated onscreen avatar to present teaching sessions (described here as a virtual tutor) have proven to be successful (Cole, 2003; Massaro & Bosseler, 2003) but RFID-enabled input and virtual tutor-led lessons have not been combined to teach symbol-based communication using PECS pedagogy. Therefore, the aim of the research was to develop and evaluate a CAL system capable of teaching PECS symbol-based communication to children with autism who had limited or no verbal communication using a virtual tutor. The participants attended a local UK Special Educational Needs (SEN) school. All of the children had a diagnosis of autism, had very limited expressive language and were already familiar with the PECS system. The scope of this research was to investigate the viability of a computer-based alternative to conventional PECS teaching methods making the research a useful first step toward supporting non-verbal children's communication needs earlier in their development (See future work in Chapter 7).

The research consisted of three stages. In the first stage, an initial design was implemented. The system design was informed by the literature (described in Chapter 2 'literature review'). The development of a prototype system included the design and creation of an input method called RFID Bridge. RFID Bridge used Radio Frequency Identification (RFID) enabled laminated symbols, similar in look and feel to PECS symbols used by children with autism (see Chapter 4 'Design of a computer-based PECS system'). The system was tested by a verbal child with autism and results from the testing were used to build a proof of concept system called Computer Assisted Picture Exchange version 1 (CAPE V1).

The second stage tested this system in a pilot study with eight children with a diagnosis of autism who could express a maximum of one-word sentences. Children taking part in the pilot were encouraged to interact with CAPE V1. During the pilot participants were observed and results were analysed using a mixed methods research approach (see Chapter 5, Sections 5.3 and 5.4).

The literature provided a number of examples of CAL systems used by children with autism with limited or no functional speech that featured avatars. These research studies have shown that children with autism enjoy taking part in activities that includes taking part in social interaction with avatars (Leopold, 2007). Avatars with little or no use of facial expressions that emphasis emotions (smiling, frowning and scowling) also seemed to be preferred by children with autism than those of avatars with emotions being used. If children with autism do prefer to communicate with avatars then it is possible that lessons that are led by a virtual tutor may help them to improve their understanding of some curricular subjects.

A number of the studies used avatars with a synthetic voice as verbal output however, one study suggested that children with autism who could communicate using speech and their teachers found the output "too synthetic" (Williams et al., 2004). The pilot therefore tested voice type (synthetic vs. natural) to see if verbal output affected non-verbal children's ability to interact with a computer-based system. This stage of the research is reported in Chapter 5 'pilot study results'. Results from the pilot informed the design of a CAPE V2 teaching system, later used in stage 3 of the research.

Children with autism who have speech and language impairment often have difficulty understanding verbal instructions. The literature suggests that this may be due to a deficit in the way they process auditory information. Auditory processing can for example be influenced by the length and speed of a virtual tutor's utterance. The amount of fluctuation in tone and pitch (often used to convey emotion in utterances) or prosody in the utterance can also influence understanding for children with autism (McCann et al., 2007). Some of the children in the pilot study were identified by their teachers as having auditory processing impairments.

Children with autism have difficulty initiating and continuing social interaction with others. The rules of social interaction are often difficult for this group of children and they find the rules of social interaction difficult to follow (Thiemann & Goldstein, 2001). In the pilot study children took part in very few instances of social interaction however by the end of the study the number of social interactions the children initiated with the teacher increased.

Verbal (speech) and non-verbal (for example, pointing) are delayed and for some children will never improve communication (Boesch et al., 2013). The literature suggests that using approaches to improve communication (Howlin et al., 2014) and social interaction (Wetherby & Woods, 2006) should be used to provide useful therapeutic interventions for this group of children.

The research produced findings consistent with these three issues; children who took part in the study were initially reported by their teachers to have difficulty understanding verbal instructions, had difficulty engaging in social interaction and had limited or no verbal communication. The research confirmed these issues, however, over the course of the research children demonstrated increased use of

verbal and non-verbal communication and engaged in spontaneous social interaction with the teachers.

The final stage of the research tested the CAPE V2 teaching system with five children who were able to express a maximum of one-word sentences in any one utterance. The children were between the ages of 9.2 and 10.3 years and testing took place over four weeks. The CAPE V2 system was designed to teach new symbols and numeracy skills lessons and was customisable to each child's individual needs. The research approach was based on a Formative Experimental approach (see Chapter 3, Section 3.2), combined with a Mixed Methods analysis approach. Results from this stage are reported in Chapter 6 'main study results'.

1.5. Research ethics

Working with children with special needs presented a number of ethical considerations that informed the research design.

The interests and rights of participants taking part in the study were protected by:

- adherence to The Open University research ethics requirements

- obtaining the prior agreement of parents or guardians

- conforming to requirements of U.K. statutory legislation concerning child protection

- compliance with the host school's procedures (safety and codes of conduct)

- ensuring that the continuity of participants' education was prioritised

Ethical considerations and safeguards are discussed in more detail in Chapter 3, Section 3.6 of this thesis.

1.6. Thesis structure

This thesis consists of this introductory chapter (Chapter 1) and a further five chapters describing key stages of this research flowed by a discussion and concluding comments in Chapter 7 and are summarised next.

Chapter 2 provides a brief overview of autism and reviews the substantive literature relating to traditional and technology-based teaching approaches for children and young adults with autism. The chapter concludes with observations of significant gaps in the literature worthy of further research.

Chapter 3 describes quantitative and qualitative research methods, as used in this research study. The chapter focuses on analysis approaches which are appropriate to research with small groups of participants with differing levels of impairment, including communication (verbal and non-verbal), social interaction and level of learning disability. The chapter concludes by outlining the methods used during the two research studies described in Chapters 5 and 6.

Chapter 4 describes how a computer-based PECS system, known as Computer Assisted Picture Exchange (CAPE) was designed, tested and developed. This chapter outlines the primary developmental stages of CAPE and the three CAPE variants that were tested. These were a functionality-testing environment called CAPE Simulator, a proof of concept called CAPE V1 and a learning environment called CAPE V2.

Chapter 5 describes the pilot study, which tested CAPE V1 to establish if non-verbal children with autism were able to interact with a virtual tutor using a physical symbol user interface. The pilot study was also used to investigate how a computer generated virtual tutor's voice type affected children's use computer-based learning. In addition, the study allowed the system's physical symbol input interface to be tested to see if it allowed participants to interact with a virtual tutor in a similar way to a child's communication with a communication partner in traditional PECS symbol communication.

Chapter 6 describes how the new CAPE (CAPE V2) system was evaluated, modified and used to teach numeracy skills to non-verbal children with autism and support symbol-based communication. The chapter looks in depth at the qualitative and quantitative results from the main study and discusses how effectively CAPE V2 was able to meet the individual learning needs of the children in the study.

Chapter 7 considers the effectiveness of CAPE as a symbol-based communication-teaching tool in light of findings from the pilot and main studies and compares these findings with those others in this field that were outlined in Chapter 2. This chapter goes on to outline further work that could be carried out.

Chapter 2: Literature review

2.1 Introduction

This chapter presents an overview of autism (Section 2.2) and considers how technology has been used as part of the learning process for affected children. It presents a framework for technology-supported learning (Section 2.3) and explores how, within this framework, technology might inform the development of an alternative teaching approach for children with autism (Section 2.4). This chapter also discusses different types of educational approaches described in the research literature and concludes by identifying some potential gaps in the literature relating to educational interventions.

2.2 What is autism?

Autism is a neuro-developmental disorder (LaCroix et al., 2009) with impairments in social behaviour, speech and communication (Lindsey-Glenn & Gentry, 2008; Mateson & Wilkins, 2009), cognitive flexibility (Ozonoff, 1994), a failure to generalize and an inability to understand others' intentions or to see things from others points of view, due to a Theory of Mind deficit (Baron-Cohen, 1985). Children with autism find it difficult to learn skills by observing and imitating other peoples, behaviours (Hobson, 2004, p. 215-223) and lack the ability to take part in symbolic play (Hobson, Lee, & Hobson, 2009) where an object substitutes or takes the role of another unrelated object (for example, typically developed children in symbolic games may use a wooden brick as a toy car). The causes, frequency and the way this developmental disorder is defined have all been contested.

However, these debates are not pertinent to the aim of this research and will not be considered in this thesis.

Evidence suggests that autism may be present before birth (Coleman & Betancur, 2005, p. 9; Stoner et al., 2014). However, diagnosis of autism is based on the child's behaviour rather than medical testing such as a blood test (So et al., 2013). Autism is typically diagnosed by clinicians at around 3 years of age when delays in typical developmental milestones are not achieved (Kishore & Basu, 2014). Autism is believed to be a disorder that will affect the individual for the whole of their life (Matson & Kozlowski, 2011).

The prevalence of autism can be reported using different measures; government agencies like the Department for Education (DfE) may discuss prevalence of autism in terms of a percentage of a target population such as the percentage of children with autism in the UK education system. More frequently autism is discussed in terms of the number children with a positive diagnosis in a given sample group. However, no matter which method is used it has been generally agreed that positive diagnosis of autism has increased dramatically over the last thirty-four years. For example, Wing & Gould (1979) estimated that, at that time, approximately 5 in 10,000 people had autism in the United Kingdom. A study in 2006 estimated the prevalence of autism in the South Thames region of the UK was 38.9 per 10,000 people (Baird, 2006). Alarmingly, the Department of Health suggest that as many as 1 in 100 [or 100 in 10,000] people in the UK could have autism or an autism spectrum disorder (Department of Health, 2012). Generally, large increases in the number of children being enrolled in Special Educational Needs schools have also been reported. For example, the UK Department for Education state that

"between 2005 and 2010...the number of pupils with speech, language and communication needs has increased by 58 per cent, to 113,000 pupils; and the number of children with autistic spectrum disorder has increased by 61 per cent, to 56,000 pupils" DfE (2011, p. 20).

Recent research suggests that, despite a five-fold increase in the numbers of children with a diagnosis seen between the 1990's and 2012, the annual prevalence rates for children between the ages of 2-8 years has stabilised, with approximately 3.8/1000 [38 in 10,000] boys and 0.8/1000 [8 in 10,000] girls with a diagnosis of autism in the UK (Taylor et al., 2013). The apparent increased prevalence of autism may be accounted for by a number of factors. Baird (2006) observes that

> *"[i]n addition to a true increase in prevalence, alternative explanations have been proposed, including changing diagnostic criteria, different methods of ascertainment, varying urban, rural and country location and population study, younger age, and inclusion of individuals with average age intelligence quotient (IQ) and those with other neuropsychiatric and medical disorders"* Baird et al (2006).

In addition to the points raised by Baird et al., (2006), Matson & Kozlowski (2011) observe that inaccurate diagnosis by less experienced clinical or educational psychologists and increased awareness of autism may have some influence on the prevalence of diagnosis.

As Baird et al. (2006) and Matson & Kozlowski (2011) suggest, our understanding of autism and the widening of the diagnostic criteria may have influenced the increase in positive diagnosis. For instance the American Psychiatric Association's

fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM IV) included children with "autistic features" in the diagnostic category Autism Spectrum Disorder (ASD) who previously would have been categorised as having retardation or having social communicative issues (Siegel, 2003, p. 14). The update to DSM IV (DSM V) has further extended the group of people considered to have an Autism Spectrum Disorder with the inclusion of children who were previously categorised as having autism (American Psychiatric Publishing, 2013). The research reported in this thesis was carried out under the guidance of DSM IV; therefore, this thesis will refer to DSM IV rather than its replacement (DSM V).

This thesis uses the term 'autism' to describe individuals who exhibit the triad of impairment which includes: delays or an ongoing absence of verbal communication, social interaction and social imagination development (Kanner, 1943). Individuals who are considered to be on a part of the autism spectrum but only exhibit some of the triad of impairment, or are less severely affected, will be described here either as being on the autistic spectrum, having an ASD, or by their individual diagnostic term, such as 'Aspergers'

It is long established that, approximately 75% of people with autism have some form of intellectual disability and 50% have a severe learning disability, with an IQ below 50 (Howlin, 1998). People with autism also lack the ability to communicate verbally, which impacts on intellectual development and social interaction skills. For a small proportion of children, a lack of speech will be a lifelong disability (Adams et al., 2012; Howlin et al., 2014).

Educational strategies in UK SEN schools

Typically, educational strategies for teaching children with autism are based on one-to-one education in small classroom settings, using structured teaching methods, such as TEACCH (Treatment and Education of Autistic and related Communication handicapped CHildren) (Jordan et al., 1998, pp. 6; Wall, 2006, pp. 86-88; Boyd et al., 2014). The TEACCH approach provides guidelines for working with children with autism from the perspective that interventions should be tailored to support each child's needs while taking advantage of the child's strengths (Blugaugh & Kohlmann, 2006). Techniques such as Applied Behavioural Analysis have also been used to aid therapists to promote useful skills and develop socially acceptable behaviour, for example by helping to reduce aggressive or socially inappropriate behaviours (Malik, Saeed & Malik, 2013). These behaviours have been seen as coping strategies resulting from the need to gain control in a confusing world (Kearney, 2008).

Social communication problems have been tackled by using communication interventions such as Picture Exchange Communication System (PECS) that use the exchange of one or more physical graphic symbols to request objects or events the child wants. PECS has proven to be a useful communication intervention for people with autism who are either non-verbal, or have emerging verbal ability (Raultone et al., 2010). The success of PECS is due to its use of symbols as pictorial representations of individual wants and needs, and the physical social interaction it provides via symbol request/exchange (Bondy & Frost, 1994, p. 67-93).

Communication using PECS usually consists of a communicator (the child with autism) and the communication partner. PECS has six levels of use ranging from servicing the individual's basic wants and needs in the initial stages to two-way and often spontaneous communication between the child and his/her communication partner in stage six (Frost & Bondy, 2002, pp. 67-240). The PECS communication method is usually instigated when the communicator constructs a request of one or more symbols from a folder that represent objects or events that the child may wish to request (Bondy, 2012), referred to here as the PECS folder. Request symbols are attached to a small board, known as the "sentence board", and passed to the waiting communication partner. The partner then confirms the request verbally and presents the communicator with the requested item or action (Frost & Bondy, 2002, pp. 159-172).

PECS is often introduced when the child begins primary education at 5 years old. Introducing interventions like PECS earlier in the child's development could, however, have a positive influence on social communication (Wetherby and Woods, 2006; Cafiero, 2008). Addressing communication deficits earlier in the child's development is seen as a way to reduce a child's frustration and anxiety. This anxiety has been seen as linked to the development of 'comforting' repetitive behaviours (Greenspan & Wieder, 2006), which have an adverse impact on children's social and communication skills. Early support regarding communication skills may reduce the likelihood of this occurring (Wetherby and Woods, 2006; Bercow, 2008).

The targeting of special needs support services and school special needs coordinators can be understood in the wider context of technology and pupils with special needs. Much information and communications technology has been seen

as being of particular value for pupils with special educational needs and their teachers. Internet access and technology has now become more accessible to mainstream and SEN schools with greater use of technology in classrooms. For example, the Department of Children Schools and Families (DCSF) noted that

> *"Children with SEN and disabilities use a wide range of equipment, such as interactive whiteboards and/or plasma screens, computers, touch screens, adapted keyboards and access technology, or switching equipment "* (DCSF, 2012, p. 61).

ICT has been used to address impairment and learning difficulties for children with special educational needs (discussed further in Lewis (1999)) Which is still pertinent today. In summary, these are:

- Interaction (e.g. using devices activated by movement, such as sound beams)

- Communication (e.g. devices activated by puff of air or muscle contraction)

- Physical control (e.g. epileptic seizures may be controlled sufficiently, using technological devices, to enable pupils experiencing these difficulties to participate in inclusive classrooms)

- Access to the normal curriculum (a vast array of devices, linked with hardware e.g. alternative "mouse" devices giving pupils access to curricula from which they would have been barred previously)

- Subject-linked learning (including image manipulation, art appreciation using museum or gallery-based packages, simulations, databases, etc.)

- Reward/motivation (certain pupils may enjoy working on a computer because it frees them from interacting with other people, but teachers may have reservations about encouraging such isolation).

In terms of autism, there is evidence to suggest that people with autism like to interact with onscreen content like computer video games (Shane & Albert, 2008; Mineo et al., 2009; Ferguson et al., 2012, p. 249). Consequently, this interest in computer delivered content has been used as a way of addressing impairments often associated with autism. For example, computer related teaching methods are believed to increase the attention of participants' with autism (Verenikina et al., 2010), social interaction with others (Wright et al., 2011), Theory of Mind, motivation (Parsons & Cobb, 2012; Bauminger-Zviely et al., 2013), curiosity and length of time the participant spends on a subject (Williams et al., 2002). These results may point to a way of helping children with autism to achieve a higher level of engagement in the learning process and a higher level of understanding by using pedagogical approaches that make use of Computer Assisted Learning (CAL) based technology.

CAL allows participants to repeat key tasks consistently without any constraint of tutor facilitation or tutor fatigue (Cromby, 1996). This was found to be especially important for pupils with autism who might benefit from repeated exposure to concepts as part of their learning.

Historically, concerns have been voiced that computer-based interventions may stifle social interaction and language spontaneity (Bernard-Opitz, Ross, & Tuttas 1990; Powell 1996). However, these concerns have been contested and a number of additional benefits of CAL have been highlighted in the literature.

CAL can promote spontaneous commenting and a reduction in echolalia and inappropriate behaviour (Williams, 2002, Massaro & Bosseler 2003; Goldsmith and LeBlanc, 2004; Whalen, 2006). Parsons argues that computers also offer a predictable and familiar environment where auditory and visual inputs can be controlled to help remove distractions from the task (Ferguson et al., 2012).

In summary, these benefits suggest that computer-based technology could provide children with autism with a useful framework for learning new skills.

2.3 ICT, CAL and CAI, a framework for learning

Since the advent of the personal computer and the increase in availability of Internet technology, CAL-related education packages have become more accessible for Special Educational Needs (SEN) curricula aimed at children with autism in the United Kingdom. Research studies have changed educational support delivery for children with autism by refining teaching methods and increasing the provision of specialist technology, with a growing number of applications and software being designed for children with autism. However, evaluated pedagogical software targeting communication skills remains rare (Ramdoss et al., 2011).

Technology as an influence on teaching

Historically, technology-based methods to teach children with autism have focused on addressing specific impairments in communication or social skills. However these approaches have lacked a definitive framework that outlines how technology can be combined with educational practices to provide new ways of teaching children with specific learning needs, such as autism.

The Teacher Embodiment and Learner Affordances Framework (TEALEAF),
created by Sheehy (2010), has bridged the gap by exploring different ways of
providing teaching support (physical or virtual tutors) and the environment the
pupil will use (physical or virtual environments).
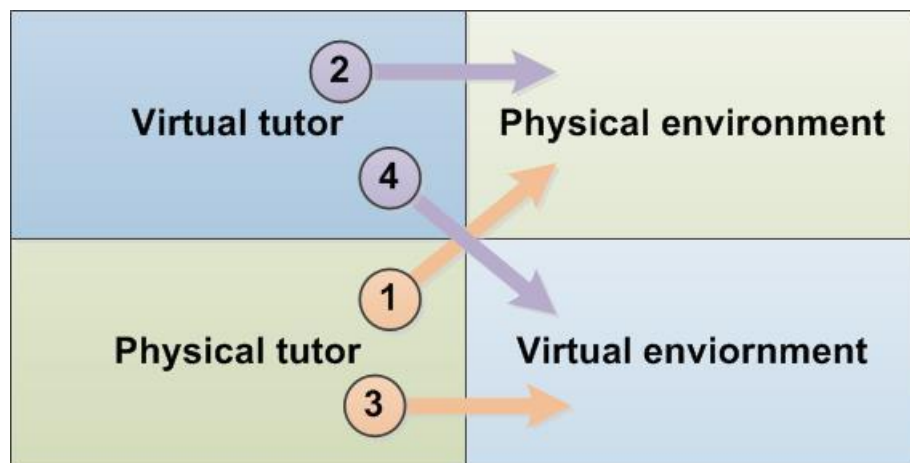
Figure 2.1: The TEALEAF framework

Basic examples from the TEALEAF framework are shown in Figure 2.1 and
described below:

1. Physical tutor and physical environment: a traditional way of teaching
   children of all abilities: in this scenario, lessons are teacher-led and CAL
   provides an alternative to traditional teaching tools, for example, an
   interactive white board is used in place of a chalkboard.

2. Virtual tutor & physical environment: the tutor consists of a computer-
   generated character that interacts with real objects in the learning space.
   For example, if a virtual tutor reacts to a child's interactions with a toy that is
   embedded with motion sensors.

3. Physical tutor & virtual environment: in this method, the pupil is guided by his or her carer/teacher, but interaction is carried out with virtual items via input devices such as a mouse or keyboard.

4. Virtual tutor & virtual environment: a computer device provides interaction and guidance, with no overt assistance from a physical tutor, or the tutor interacts with the pupil via an avatar. For example, when a child interacts with others in a social networking environments like Second Life (discussed later).

Sheehy (2010) argues that the divisions between virtual and real tutors and the teaching environments are permeable and that different aspects of the Teacher Embodiment and Learner Affordances Framework (TEALEAF) described above highlight different affordances for people with learning difficulties.

2.4 Computer Assisted Learning research

Technology may act as an alternative educational support for children with autism. Moore, McGrath and Thorpe (2000) have suggested a framework for research and development relating to CAL and autism. They stated that any future research should aim to address one or more of four core features of autism. Sections 2.5 and 2.6 discuss technology-based educational research that target two of the core features of autism that Moore, McGrath and Thorpe (2000) highlighted for future research. These are social skills education and communication skills education. These are discussed next.

2.5 Social skills education

A number of research studies have used technology to address social skills impairments in children with autism. The approach varies from individual use of technology to group working and distributed social networking (Abbott et al., 2011; Burne et al., 2011; Rdau & Macintyre, 2012) and peer-to-peer communication with therapeutic robots (Weir and Emanuel, 1976; Robins & Dautenhahn, 2006; Wainer et al., 2014). The variety of approaches has allowed researchers to address different aspects of social interaction which include peer relationships and collaboration with other people. This section discusses how technology has been used to encourage and teach social interaction, based on the following research areas:

- Encouraging peer relationships with virtual peers

- Social interaction with robots

- Social interaction and collaboration with avatars

Encouraging peer relationships with virtual peers

Issues with peer relationships can cause social isolation for people with autism (Schohl et al., 2014). A study by Tartaro & Cassell (2008) tested the hypothesis that children with autism can learn key peer communication and social skills more effectively when supported by a computer-generated virtual peer called Play and Tell (PAT), compared to learning via normal peer-to-peer interactions.

The study implemented a full size, gender ambiguous avatar named Sam who interacted with the participants via a full size plasma screen. Sam had limited facial details (to help achieve gender ambiguity) and limited facial expressions. Using a less detailed facial representation helped to reduce some of the issues

believed to be associated with over stimulation, such as eye movement by communication partners. An example of the Sam avatar can be seen in Figure 2.2.

Figure 2.2: The virtual peer known as Sam (Leopold, 2007)

The PAT environment included a model house. The rear walls of the house were removed and the remaining part of the house was placed against the plasma screen. The missing wall was created in the virtual environment to give the impression that Sam was interacting with the house during play. The participant's section of the house had Radio Frequency Identification tags (RFID) attached allowing Sam to keep track of play, etc. (see Chapter 4, Section 4.4 for an explanation of RFID technology).

Tartaro & Cassell (2008) stated that PAT was created to provide the following features, believed to be important for the provision of a useful social intervention:

1. A virtual peer context for children to practice peer social interaction skills.

2. That tells a story to the child as a way of practicing imagination and language.

3. A system that is controllable and by the child to allow children with autism to come to understand their own communication and reciprocal social interaction in typical social settings.

An additional goal of the system was to allow researchers to better understand the mechanisms underlying the communicative deficits of autism by observing children in this group interacting with the storytelling virtual peer (Tartaro & Cassell, 2008).

The study found that participants engaging with Sam expressed a higher volume of verbal communication during a teaching session compared to similar length sessions with real peers.

Social interaction with robots

Robots have been used in educational research to deliver social and educational interventions for children with autism since the 1970's (see Weir & Emanuel, 1976; Michaud et al., 2003; Robins & Dautenhahn, 2006; Dickerson et al., 2013). For example, Weir & Emanuel (1976) researched the possibility that robotic devices could support educational or therapeutic interventions for children with autism. The study used a remotely controlled turtle constructed of Lego bricks and controlled using the Logo programming language. The study was undertaken with only one 7-year-old participant, so no generalised conclusions could be drawn relating to positive outcomes for children with autism as a whole.

Since Weir & Emanuel's early work a number of researchers have explored how robots can be used as a therapeutic intervention for children with autism. One

example is the Université de Sherbrooke in Canada where robotic research has been conducted with children with autism since 1998. Findings from several of their studies, (e.g. Michaud et al., 2003) have led them to conclude that it is not feasible to design a robot capable of acting as an effective pedagogical tool for all children with autism, due to the vast range of different deficits and skills exhibited.

Michaud et al., (2003) found that during the creation of their robotic devices it was important to adhere to design principles that take account of key characteristics of autism. By doing this Michaud et al. were able to produce devices that are more appealing to children with autism. Design principles include:

- The physical appearance should engage the child's curiosity. Designs that have proven successful include round shapes, primary colours and different textures, though it is important to ensure that any materials used are safe and washable. Moving parts such as arms or other appendages have also proven to engage participants' interest, as do removable parts.

- Many children with autism have issues with audio hypersensitivity so it is important to avoid loud, high or low-pitched sounds.

- Care should be taken when incorporating symbolic games. Children with autism have deficits relating to imitation so devices incorporating symbolic games should aim to support learning these skills.

- Images and photos are a more effective way of representing an object or event than words for children with autism. In addition, the device should use simplified short messages (three words or less) which are frequently repeated to support learning. Messages should also refer to concrete things rather than abstract thoughts and concepts.

- Design of devices for children with autism should take into account the individuals who will use them. Each child has individual needs, which must be addressed if the tool is to be a successful intervention.

(Michaud et al., 2003).

The Michaud et al. guidelines are a useful design aid for equipment intended for use by children with autism. The guidelines can be generalised and may complement ICT design frameworks not directly connected with robot intervention research.

Another robotic project of some note is AURORA (Autonomous Robotic platform as a Remedial tool for children with Autism) in the United Kingdom. AURORA has focused all its work on robots, which are intended as therapeutic educational toys, and investigating the way children play and interact with robots. AURORA's main aim was to discover how social and imitation skills could be encouraged in children with autism. In addition, researchers wished to see if robots could be used as a medium for shared attention and for encouraging peer to peer and child to adult communication (Davis, 2006; Francois, Polani, Dautenhahn, 2007; Billard et al., 2007; Dickerson et al. 2013).

AURORA studies differ from research by Michaud et al., (2003) by incorporating Conversation Analysis (CA) as part of their study method. CA provides an empirical framework that allows researchers to analyse verbal and non-verbal expressions produced by a participant. In two AURORA studies no control group was used (Robins et al., 2005; Robins & Dautenhahn, 2006); instead, positive participant behaviour observed in the research was compared to behaviours previously observed in neuro-typical children with similar developmental levels.

In a study by Robins et al., (2005), it was hypothesised that children with autism who have repeated exposure to humanoid robots with simplified facial features would show an increase in basic social interaction skills. The study tested the theory by introducing participants to an actor dressed as a robot (termed a "theatrical robot") with his facial features obscured by a mask. In a second test, participants were introduced to the same actor wearing normal clothes with no facial obscuration. Robins et al. found that participants with autism showed a notable increase in social interaction with the "theatrical robot" compared to interactions with a person dressed normally and with no facial obscuration.

Examples of characters with limited facial expressions similar to those of the "theatrical robot" can be found in children's entertainment. Many children with autism have an affinity for cartoon characters and Computer Generated Imagery (CGI). This may be because these characters tend to have lower levels of facial communication compared to real people. In addition to this, characters like Buzz Lightyear have easily memorised catch phrases (Siegel, 2003, pp. 260).

Robins & Dautenhahn (2006) built on their 2005 study by using robotics as a mediation channel for communication between children with autism and children who had no developmental disorder (termed here as typically developed) helpers (in this case the experimenter). Generally, during human robotic interaction studies the role of the experimenter is to act as an observer, not to interact with the participants in the study. In the (Robins & Dautenhahn, 2006) trial, however, the experimenter was an active participant.

During the study, a robot doll named "Robota" was used. Robota was configured with two modes:

1. To dance to a selection of pre-recorded pop, classical music and children's nursery rhymes favoured by the children.
2. To act as a puppet, remotely controlled by the experimenter (with control of the arms, legs and head of the doll).

Three children with autism aged 5, 7 and 10, with limited or no language, participated in the trial. Robins & Dautenhahn, (2006) found that all three participants actively interacted with the experimenter during the trial. For one of the participants interactive behaviour had not been observed before, highlighting how robotics can be used as a mediator to instigate communication between participants, robot and the researcher or therapist.

The study demonstrated that social interaction increased between the participant and the researcher if the researcher was active in the process. The study, however, consisted of only three children with autism, with similar Verbal IQ (VIQ) and performance IQ (PIQ). This made it difficult to generalize the research findings to children with autism who have differing developmental levels or social communication deficits.

Dickerson et al. (2013) have continued research into the possible benefits of using robots to influence children with autism to take part in social interaction. Dickerson et al., demonstrated that a child with autism initiated social interaction with a researcher and expressed empathy for a robot called KASPER. The study was designed to capture data that included video recordings of the child's behaviour prior to, during and after the study, which Dickerson et al. argue provided a richer understanding of the child's social interaction development over eight sessions (Dickerson et al., 2013). However, because this study was conducted with only

one child and because of the diversity of level of impairment of children with autism, the findings cannot be generalised to the autism population as a whole.

Wainer et al., (2014) conducted a pilot study with six children with autism between the ages of 6-8 years, to understand whether the children were more likely to collaborate with a robot or a human to play a computer video game. The children experienced two conditions; in one condition the child interacted with a human collaborator and a second condition were the child interacted with KASPER who was previously used in Dickerson et al., (2013) (see Figure 2.3).

Figure 2.3: KASPER (Wainer et al., 2014)

Children took part in four sessions of approximately 25-minute duration, with each condition presented alternately. For two sessions the children worked with a human collaborator. For the remaining sessions the children worked with KASPAR. Results suggest that the children found KASPAR more engaging and took part in more instances of social interaction than with a human collaborator.

However, the number of social interaction instances also increased over the two human collaborator sessions.

Social interaction and collaboration with avatars

Avatars have been used to support social interaction and collaboration in place of a physical tutor in virtual environments. Virtual meeting places allow people with autism to engage in conversations without having to interpret the subtle communication and social interaction etiquette present in face-to-face communication. Uses for communication via avatars include rehearsals for events such as a school trip, or to help participants to deal with a specific social interaction in a safe environment (Parsons & Cobb, 2011). These interactions can be repeated as many times as needed.

The use of avatars has the potential for creating peer-to-peer social interaction with carers supporting the individual interacting with a desktop virtual environment (DVE) (Moore et al, 2005). A DVE provides the child with access to a computer-generated simulation of the real world using a desktop computer (Fornasari et al., 2013). DVEs also have advantages compared to virtual reality when presented through head mounted display; DVE is less likely to cause physical side effects, such as nausea and loss of balance (known as cyber sickness) which has been found with virtual reality when presented through a head mounted display (Parsons, Mitchell & Leonard, 2004). Also, DVE is less costly to implement, increasing its availability.

A number of Desktop Virtual Environment (DVE) applications have been used in autism research over the last ten years. One example of a DVE is an application called Virtual Café. A study by Parsons, Mitchell & Leonard (2004) used Virtual Café to help participants improve their social understanding, by exposing them to

situations where they could attempt reasoned judgements in a safe, virtual environment.

The Virtual Café study investigated the potential of DVEs with a clearly specified population of children with autism and children with similar verbal ability and physical ages who did not have a diagnosis of autism.

Testing was undertaken in two phases. In the first phase, the participants undertook five of the six tasks outlined in the Behavioural Assessment of Dysexecutive Syndrome (BADS). BADS are a series of tests to assess an individual for executive function impairments, which include difficulties in organising, planning, initiating and adapting behaviour (Wilson et al., 2003; Hughes et al., 2013). Data from BADS was converted into a 0 to 4 standardized performance scale.

Participants in the study were assessed on their level of expressive language (known as Verbal Intelligence Quotient or VIQ) and their ability to complete tasks (Performance Intelligence Quotient or PIQ). Participants were split into two groups. One contained individuals with autism and typically developing children matched on PIQ. A second group contained children with learning difficulty with a similar level of VIQ to that of the autism group but did not have a diagnosis of autism acted as a control group.

The study found no significant difference between Verbal IQ (VIQ) and autism groups. Of the two groups, the performance IQ (PIQ) showed the best performance compared to the autism and VIQ groups in four of the five tests. Results from the pilot study confirmed that the use of DVE could improve performance with participants with autism after only a few sessions. The results are of particular interest as ASD participants were able to increase performance in

task-based tests in the Virtual Café in spite of having specific executive function deficits compared with their VIQ peers (Parsons, Mitchell & Leonard, 2004).

In a later implementation of Virtual Café, four task levels were introduced; level one provided six tables, all of which were empty. For each level, the participant began the game at the café checkout and would be provided with a panoramic view of the café area and asked simply to "find a place to sit". The student was encouraged to click on a seat of his/her choice and receive feedback relating to the choice made. Successive levels (2 to 4) simulated a progressively busy café with fewer spare places to sit. Mitchell, Parsons & Leonard (2007) found that participants with the lowest verbal IQ scores showed the greatest improvement in social understanding; however social improvement only occurred in participants whose skills were reinforced by a real trip to the café, shortly after using Virtual Café. Those who did not have skill reinforcement shortly after the DVE sessions failed to generalize the skills learnt.

The online Desktop Virtual Environment Second Life has been used in social skills education (Biever, 2007; Kandalaft et al., 2013). In 2005, Harvard Medical School conducted a virtual social networking environment study to teach social skills to people with autism. The study made use of a secure area called the island of Brigadoon. The main aim of Brigadoon was to provide a safe environment where people with autism could socially interact. To use Second Life the children were asked to create online representations of themselves, known as avatars and communicate with each other via textual input.

The initial use of Brigadoon proved to be beneficial to users with autism. Participants found the lack of facial communication and slower interactions allowed them time to understand comments from a communication partner and

formulate an appropriate reply, rather than suffer from misunderstandings often found in multifaceted interactions, associated with face-to-face communication. It is reported, moreover, that as the original users became confident with social interaction, and more familiar with the Second Life environment, they left Brigadoon to use the less restrictive commercial Second Life environment (Biever, 2007) resulting in Brigadoon being disbanded. In 2006, Brigadoon was re-established and was still being used as an educational environment by people with autism and a group of people who have high functioning autism and speech (known as Asperger syndrome) in 2013 (Mateu & Alaman, 2013).

Social interaction has also been developed in group lessons in the classroom, using Interactive White Board (IWB) technology. IWB was an addition to ICT-enabled SEN school provision in the United Kingdom. Whiteboards and plasma screens have proven very popular with schools as they enable students to take part in group related activities rather than individual use of desktop computer screens (Slay et al., 2008).

IWB technologies have replaced the school whiteboard in some schools to allow teachers to introduce interactive lessons and group-teaching experiences for their pupils. Technologies can vary in their implementation but in general interactive white boards use projected images controlled by a central computer system and touch sensitive whiteboards, allowing the computer to calculate where, for instance, a marker has been used to repaint the screen with a computer-generated mark emulating for instance, free hand writing on a conventional white board.

Group learning via IWB technologies is emerging in SEN classrooms, but only a small number of research studies have investigated the effectiveness of this technology with people with developmental disorders (Malley et al., 2014). One such example is Verenikina, et al. (2010) who observed seven children with high functioning autism taking part in four IWB group-learning sessions. The researchers concluded that IWB increased levels of motivation and engagement in the early stages of learning. IWB also offered opportunities for children to work creatively to make or develop their own pictures or to write with their hands. However, operation of the IWB became teacher-centred and in some cases, the IWB technology, rather than the learning material, was the main object of interest. This suggests that the use of the technology in this context may not always reflect the lesson's pedagogical goals (Verenikina et al., 2010).

2.6 Verbal and non-verbal communication skills education

A primary impairment for people with autism is a delay or lack of verbal and non-verbal communication (see Section 2.2). This section will consider the following areas of communication and research investigations:

- Communication aids for non-verbal children
- Spoken language acquisition
- Influences of voice type
- Reading support

Communication aids for non-verbal children

A number of Voice Output Communication Aids (VOCA), also known as Speech Generating Devices (SGD) have been used to aid communication for non-verbal

people with autism. SGD provide the user with a digitally recorded natural voice (Bird, 2009) or synthetic voice for pre-programmed requests activated by pressing onscreen message buttons (Mirenda, 2003; Rispoli et al., 2010). Some SGD can convert a request created using a keyboard into a verbal request using a synthetic voice generation process, known as Text To Speech or TTS (Bird, 2009; Van Der Meer & Rispoli, 2010).

Researchers have combined TTS and word processing technology to provide dynamic speech support for non-verbal people with autism. An example is provided by Carly Fleischman; Carly is a non-verbal young person with autism who, until 2005, was thought to have a moderate to severe cognitive impairment. However, when Carly was introduced to a TTS-based SGD, therapists found that she was able to demonstrate a good grasp of sentence structure and meaning, in spite of having no verbal skills.

Carly's communication support continued with the adoption of the Apple iPad© as a more portable alternative to traditional computer technologies. Carly's story provides a clearer understanding of what it is like to be a non-verbal autistic child. For example, Carly stated that

> "*It is hard to be autistic because no one understands me. People look at me and assume I am dumb because I can't talk or I act differently than them. I think people get scared with things that look or seem different than them*" Fleischman (2012, p. 234).

Traditional symbol communication methods such as PECS have been developed using SGD technology. Koul & Schlosser (2004) suggest that participants demonstrated higher levels of learning using an SGD with synthetic auditory feedback than by using simple line drawn Picture Communication Symbols (PCS)

53

similar to those used in PECS. Research by Checkley et al. (2010) suggests that children with autism may prefer SGD-based interventions when compared to PECS. However only three boys took part in the study, suggesting that further research should be carried out before definite conclusions about preference can be drawn.

PECS methodology has also been emulated using SGD-based technology. In 2009 Logan Technologies in Connecticut, USA developed an SGD called ProxTalker that uses RFID-enabled PECS symbols as its primary user input method. ProxTalker has been developed as a replacement for traditional PECS symbol communication and as a way of teaching PECS to non-verbal children with autism.

Figure 2.4: ProxTalker® (Logan Technologies, 2013)

The study included two conditions; conventional PECS and ProxTalker sessions which taught the first three phases of the PECS pedagogy (physical symbol exchange, distance and persistence, discrimination between picture cards) using food items as a way to entice symbol exchange. The delivery method included a

communication partner and a person to prompt and provide hand-over-hand support for symbol exchange, similar to PECS pedagogy.

The hypothesised benefit of this approach was tested by Boesch et al. (2013), who compared PECS and ProxTalker. The study was carried out with three non-verbal children between the ages of 6 and 10 years. The participants took part in symbol selection tasks based on the first three phases of the PECS pedagogy. These were:

- phase 1 - physical exchange: the child was shown a picture card and the teacher asked the child to place it in her hand [PECS condition] or to place it on the reader [ProxTalker condition] and to receive the item of choice in return.

- phase 2 - distance and persistence: the child was asked to stand a short distance from the teacher and was encouraged to go to the teacher and place the symbol in her hand [PECS condition] or on the reader [ProxTalker condition] and to receive the item of choice in return.

- phase 3 - discrimination between picture cards: the child is taught to discriminate between up to three symbols that represented food items they liked to eat from a group of symbols that represented objects that did not interest them.

The children took part in between 39 and 71 sessions depending on their interest and availability. Each child took part in three sessions per week each of which lasted between 20 or 30 minutes. Each condition was counterbalanced to minimize carryover affects. The PECS condition followed the PECS pedagogy

while the ProxTalk condition followed a modified version of the pedagogy to allow the child to use the device to communicate with the teacher.

Results suggest that there is no significant difference between PECS and ProxTalker as a way of teaching symbol-based communication.

The ProxTalker approach relies on a human communication partner and uses physical rewards for children's correct symbol communication use. The close modelling of a symbol communication exchange on the PECS pedagogy and the inclusion of synthetic utterances to verbalise the symbol-based communication has improved the way these children communicate using symbols.

The ProxTalker approach is similar in its implementation to a new approach called Computer Assisted Picture Exchange (CAPE) that was developed in this research. CAPE was designed and developed at a similar time to ProxTalker (CAPE was initially designed and tested in 2008 and development of ProxTalker began in 2009) and adds to the technology features provided by the ProxTalker approach. For example, ProxTalker uses a combination of digital recorded voice and RFID-enabled symbols to enable communication between the child and a human communication partner using PECS symbol exchange. CAPE also uses RFID-enabled symbols as a primary user input and is designed to follow PECS pedagogy to encourage symbol-based communication. However, in the CAPE approach children communicate with a virtual tutor rather than a human communication partner. The virtual tutor leads the child through a series of learning tasks, provides onscreen reward content and allows a parent or teacher with no in-depth understanding of PECS pedagogy to help the child to improve symbol communication (see Chapter 4).

Spoken language acquisition

Desktop Virtual Environments have been used to teach speech skills to children with autism. In 2001, researchers at the Centre for Spoken Language Understanding (CSLU) at the University of Colorado decided to test an ICT-based speech therapy approach using a system called Baldi. Baldi consists of an artificial speech recognition engine, a 2D representation (on a display screen) of a head, complete with realistic mouth and facial expressions, and a keyboard-based input function. The study population consisted of six children with autism whose ages ranged from 3 to 13 years. No comparison was made with existing educational teaching methods.

The study used Baldi to teach pupils in a range of educational subject areas including Egyptian ancient history, world geography, counting, letter and word identification and the recognition of emotions. (Cole, 2003) concluded that:

> *"The learning gains, positive evaluations [...] resulting from the research exceeded all reasonable expectations."*

During the tests, Baldi did not use its speech interpretation processes (known as a perceptive agent) due to an issue with inaccurate speech recognition processes in the software version. In all tests, Baldi's responses were as a result of stimuli received from mouse input requests by the participant.

During the study, Baldi's facial expressions were limited in terms of the emotion and expressions normally present in human interaction. It is unclear from the Cole (2003) study how important the facial expressions are when people with autism use non-human interfaces in this way (see also Grayson, 2005). Participants and teaching staff expressed the view that Baldi was both helpful and effective as a

learning tool, allowing participants to repeat verbal task-based sequences without the constraints associated with a human tutor-based system.

In a later study conducted by the Department of Psychology at the University of California (Massaro & Bosseler, 2003), a variation on the Baldi system was used which included a Language Wizard and Player (LWP). The Language Wizard and Player provides recorded or synthetic voice output that can be associated with images or other visual media. Again, the population for the study consisted entirely of children diagnosed with various levels of autism and did not include any comparisons with traditional methodologies or a control group.

The LWP was incorporated into a two-phase test plan, which measured acquisition and retention of vocabulary and attempted to assess whether vocabulary acquisition was solely due to the LWP, or could be attributed to influences outside of the study such as at home or at school. Massaro & Bosseler, (2003, p. 659) concluded that:

> *"Although all of the children demonstrated learning from initial assessment to final reassessment, it is possible that the children were learning the words outside of our learning program."*

The voice quality of Baldi's inbuilt speech output software has been reported to be an issue. Some participants have described the voice output as 'very artificial' (Williams et al., 2004). The appropriateness of synthetic voice, similar to the one used in the Williams et al. study, has been contested for many years. Researchers have argued, for example, that children with autism may find synthetic voice difficult to process compared to a natural voice alternative (Hedbring, 1985; Mirenda, & Schuler 1988; Quill, 1997). However, some researchers argue that the lack of stress and intonation in synthetic voice utterances may help to increase the

child's comprehension (Schlosser et al., 2007). The Baldi software does, however, provide a facility for human voice utterances to be recorded and optionally used in limited conversational permutations.

Influences of voice type

The question of the effectiveness of real vs. synthetic voice has been the subject of a number of research studies. For example, the Gong and Lai (2003) study investigated the effectiveness of mixing synthetic voice generated by Text To Speech systems and recorded human voice found that typically developed adults with IQ levels within the normal range preferred voice utterances that included a mixture of synthetic and human voice compared to synthetic speech alone. Data relating to participant understanding of the utterances demonstrated, however, that synthetic speech was more consistently understood than utterances containing a mixture of human and digitised voice. The inconsistency between participant preference and participant understanding is believed, in part, to be due to the presence of a friendly and appealing human voice, which researchers believe may have induced an overall good feeling in the participants (Gong and Lai, 2003).

Synthetic speech has been described as difficult to follow or lacking in meaning, due to issues with prosody. Prosody, which encompasses intonation, melody and timing of speech, is important in allowing people to convey feelings, meanings and intentions to the listener (Nadig, & Shaw, 2012).

Prosody may be a key influencer for the preferred voice type for children with autism. Ramdoss (2013) has investigated how effectively children with autism can respond to synthetic and human digitised voice. This study also offered the children a choice of voice type they would like an SGD to use.

Four non-verbal children with autism took part in a total of between 13 and 18 sessions. Initially children were tested on their ability to respond appropriately to synthetic and human digitised voice requests from an SGD. The children were then assessed on their mastery of using the SGD (based on the percentage of appropriate responses they made in the early sessions). Three of the children who used the SGD were then given a choice of two SGD devices, one with a synthetic voice and another with a human digitised voice. The children were shown both devices and asked to choose which one they would like to use. This process was repeated over a number of sessions and their choices and their ability to respond to responses were recorded.

Results suggest there are no significant difference in appropriate responses or choices of voice type by the children. Ramdoss suggests that this was due to differences in the number of sessions each child participated in and their ability to use the SGD. For example, Child 1 took part in only 13 sessions and chose the synthetic voice-enabled SGD 70% of the time. Child 2 chose digitised voice 67.5% of the time and Child 4 chose each of the voice conditions 50% of the time. However, Child 3 found the SGD difficult to use and did not take part in the choice phase of the study.

Although Ramdoss (2013) results are inconclusive it does call into question the view that synthetic voice is less useful due to the artificialness of its utterances (Williams et al., 2004) This result suggests that further work may be required to see if voice type does have an influence on how children with autism use technology.

Future studies in this area may lead to more supportive communication aids and ICT pedagogical tools in the future. As Williams et al. (2004) noted, some children with autism found synthetic voice too artificial. Given the mixed and incomplete evidence regarding voice preference in the literature surveyed, it was considered important in the present study to determine the level of preference of participants for human or synthetic voice types.

Reading support

Reading skill acquisition for children with autism has long been carried out using a one-to-one teaching process. For children with autism this can be a long and difficult process due to low levels of learner motivation and issues with rigidity of thought, unless the subject material relates to the individual's specialist interest.

A number of research studies have investigated ways of supporting reading for children with autism (Whitcomb, Bass and Luiselli, 2011). For example, a pilot study conducted by Williams et al. (2002) explored the possibility that a CAL-based intervention could support autistic children more efficiently than traditional reading tuition. Prior to the study, Williams et al. hypothesised that children with autism would concentrate more on a CAL delivered reading book, they would instigate fewer interactions with the adult supporting their reading and a greater number of words would be learned compared to traditional reading methods.

The study population consisted of eight children with autism and chronological ages from 3.1 to 5.9 years. The children's relative developmental levels were tested using the Autistic Diagnostic Interview (reviewed) (ADI-R) ratings, allowing them to be grouped by their age and level of developmental impairment. The children were split into two equal cohorts of four children matched as closely as possible with their level of impairment.

One cohort was assigned to the computer related activity and the other cohort assigned to a traditional reading book activity. In the first phase of the study, cohorts spent a total of fifteen minutes per day, for ten weeks, assigned to their associated intervention. Once phase 1 was complete, the set tasks were exchanged and a further ten-week trial was carried out. Each of the cohorts had a teacher known by the population who remained with their assigned cohort for the length of the trial.

Williams et al. found that children in each of the cohorts consistently spent longer focused on computer related reading activities compared to traditional reading activities. Computer-based reading scored a mean of 9.9 minutes of a fifteen-minute session compared to the traditional reading task which had a mean score of 2.8 minutes.

In spite of Williams et al. hypothesis that the children were more likely to reduce interaction with the supporting teacher when using a computer, the study found that social interaction actually increased. Requesting help or showing items of interest increased from 27 instances during the traditional method to 111 times in the 15 minute session when using a computer. Also, language use increased from a mean of 44.6 words used during the book reading sessions compared to a mean of 99.5 words during the computer sessions. The study therefore demonstrated an increase in language and social interaction during computer use compared to traditional reading methods. Similar results have also been seen in a reading study by Whitcomb, Bass and Luiselli (2011) who used a computer software package called HeadSprout[©] to teach words and word sounds over 23 teaching sessions with one 9 year old child with autism.

The Williams et al. study length was considered by Williams et al. to be too short to produce large increases in reading ability and would probably have been more successful as a longitudinal study. The study also did not consider if increases in the time the children attended to the computer generated book would continue for an extended period, or would reduce later once the intervention's novelty effect dissipated.

It should be noted that increases in social interaction during computer use relied on the use of the package as a teacher-assisted system rather than a purely system driven intervention. The use of technology in this way helps to support the view that CAL interventions can be beneficial when human support is provided within the intervention design (Jordan & Powell, 1990).

2.7 Summary

Children with autism exhibit a number of social, behavioural and communication impairments. Each of these impairments has a detrimental effect on the child's ability to interact with the world around them.

One of the key impairments of autism is a delay, or absence of verbal communication (Lindsey-Glenn & Gentry, 2008; Mateson & Wilkins, 2009). Research has shown that delays in early communication can result in poor prognosis for later life, increases of frustration and distress leading to social isolation, aggression and ritualized coping strategies. Research on early communication intervention has found that Picture Exchange Communication System (PECS) can influence children to make greater use of symbol-based communication and in some cases progressing to verbal communication in

children with autism. However, trained professionals are required to introduce and teach children to use PECS.

A range of studies suggests that children with autism can benefit from using computer-based interventions. In particular, CAL can help to facilitate children with autism's engagement in joint attention, social interaction, emotion recognition (Blocher & Picard, 2005) and increase their non-verbal and verbal communication skills (Williams, 2002; Whitcomb, Bass & Luiselli, 2011). For example, Robins & Dautenhahn (2006) demonstrated that triadic communication can develop between a child with autism, technology (in this case a robot) and a teacher or peer, resulting in improved social interaction and instances of joint attention.

These encouraging results suggest that this mediated method of communication support might encourage social interaction between children with autism and their peers. For non-verbal children, this type of interaction might be supported by Speech Generated Device based technologies. Research also suggests that Speech Generated Device based approaches that mimic PECS communication might provide similar improvements to PECS for symbol-based communication (Boesch et al., 2013). CAL systems that emulate traditional PECS interactions might also provide additional opportunities to influence communication and speech acquisition for children with autism who have limited or no verbal ability.

Research has shown that children with autism enjoy interacting with computer generated avatars and benefit from limited facial expressions in communication. PECS is often restricted by the availability of trained professionals. However, it may be possible to combine the benefits of PECS and avatar-based tasks by delivering the lesson using a virtual tutor. Unfortunately, CAL-based interventions that combine PECS pedagogy with a virtual tutor and RFID-enabled PECS

symbols have not been researched. This therefore led to the research aims described in Chapter 1, Section 1.2.

The next step was to consider available research methods for their appropriateness to achieve the goals of this research. These research methods, along with data collection and analysis approaches selected during this research are discussed in the next chapter.

Chapter 3: Research methodology selection

3.1. Introduction

Detailed exploration of the research context and the corresponding constraints was necessary before the most appropriate research methodologies to resolve the research questions (Chapter 1, Section 1.3) could be selected and the associated protocols developed.

This chapter begins by introducing relevant concepts from qualitative, quantitative and mixed methods approaches to data gathering and analysis and then describes how the choice of research methods was influenced by specific factors associated with the participant population and the aims of the research. The chapter goes on to identify and justify the research methods and data analysis tools adopted for this research.

A critical aspect of the intended research was to locate a suitable group of children whose school and guardians would support a trial of the proposed teaching interventions. The researcher approached a special educational needs school in the UK and discussed the school's participation in the proposed research. The school's head teacher was supportive of the school's participation, subject to teacher and parental approval. Consequently, the stakeholders in the research work included the participating children, their special needs teachers, the parents or guardians and the researcher, along with his supervisory team.

The research focused on children having a formal diagnosis of autism, in a classroom environment. The research population can be considered to include two

specific groups: children with a formal diagnosis of autism and the teachers supporting their learning. The children had severely limited verbal capabilities (at best, single word utterances) and were between the ages of 7 and 10 years. The children in the host school were in class sizes normally of five to seven pupils, supported by up to five teaching staff. This is typical of special educational needs school provision in the United Kingdom.

Children with autism can become distressed when they are exposed to new experiences, unfamiliar situations or unfamiliar people, and this was a key consideration when selecting appropriate research methodologies and protocols. The participating children's interests were prioritised at all times during the research, and audited and approved safeguards introduced to ensure children and parents / guardians' interests were protected (see Section 3.6: Ethical considerations and safeguards).

The constraints on the research had strong implications for the selection of research methodologies. For instance, the inability of participating children to articulate clearly and directly their experiences, and their likely reactions to new learning approaches, were key constraints. These factors pointed the way towards data acquisition and research methods that used mixed approaches (involving qualitative and quantitative methods) to analyse research data that was recorded during study sessions. This allowed for careful and extensive scrutiny by the researcher both during and after each study session. It was also necessary to capture the perspectives and perceptions of the teachers involved in the study sessions by arranging post session interviews. The following sections discuss the general principles of qualitative, quantitative and mixed methods and their suitability for this research.

3.2. Quantitative, qualitative and mixed method approaches

Quantitative approaches are used to help identify and explain phenomena or causal relationships between variables in an area of interest (Johnson & Christensen, 2007; Sukamolson, 2005). They are likely to follow a top down approach in which an initial understanding of the subject matter results in hypothesis generation. By testing the validity (or truth) of the researcher's hypothesis the researcher is able to provide a specific conclusion based on generalizations of the research population (Fraenkel & Wallen, 2008, pp. 15-16). For example, the experimental approach controls and manipulates a variable in the test environment such as a virtual tutor's voice type (known as the independent variable) to see how it influences the person responses to virtual tutor requests (dependent variable). By measuring potential causal relationships it is possible to conclude whether the null hypothesis (or H_0) which suggests that there would be no difference between the two voice conditions can be rejected by the available data, leading to support for the research hypothesis.

In quantitative approaches, research variables should be specified and controlled to guard against any external or unforeseen influences potentially arising within the 'natural' surroundings or from researcher influence. Quantitative approaches are expected to be rigorous and replicable to demonstrate that the results truly reflect real world events. Resulting theory may be generalizable - applicable to general populations within the subject area and in some cases, the research may result in a universal law that extends understanding beyond the initial area of study (McKereghan, 1998).

Quantitative research with human subjects often follows a between-group approach with subjects being assigned to one of two groups, depending on a pre-agreed selection criterion. In this approach, one of the groups may consist of people who may be considered to be from the general population, for example typically developed children who act as a control group. The researcher observes and measures the differences between the two groups. However, this approach provides less reliable results when smaller populations are available.

An alternative research approach for populations consisting of few participants is the within-participant approach. The within-participant approach involves the comparison of a participants interactions with all conditions and allows different sets of scores to be collected from the same research population. This approach allows the researcher to accommodate individual differences between participants in two groups.

Other approaches relay on random assignment of participants to groups to ensure that the results reflect the true nature of the participant's response to a condition. However, the within-participant approach compares the two conditions a participant has taken part in so does not need to use random participant assignment to control against bias in group assignment.

The reliability of a quantitative approach can be judged by the statistical probability the method has to show the likelihood of a causal relationship or association that exists between the dependent and independent variable (Park, 2010) which is described here as the statistical power. It is argued that within-participant approaches offer greater statistical reliability when only small populations are available because none of the population is used for control group purposes (Charness Gneezy & Kuhn, 2012).

The within-participant approach does however have some drawbacks that need consideration. In particular, ordering effects can be problematic; for example, the scheduling of an experimental activity may result in it being undertaken when a child is fatigued or too soon after a previous one, negatively affecting the child's overall performance score. 'Positive' or "practice" order influences can also arise. An example of an occurrence of a positive error is if a child undergoes a written test which then enhances the results in a later, but similar test.

To mitigate for ordering effects in a within-participant approach the population can be divided into two equally sized groups which then take part in the same research events under identical conditions, excepting that they are experienced in a different order by each group. Using such a counterbalanced approach it should be possible to demonstrate which conditions have true significance in the research event.

Quantitative research approaches are typically applied in natural science subject areas; however, social sciences researchers are frequently critical of quantitative research methods when applied to social investigations. This is particularly so where researchers are, arguably, part of the environment being studied, and contributing potentially disturbing influences to the environment they observe. Le Voi (2001) signals caution when applying quantitative (laboratory) approaches to contexts where social factors and contexts are clearly relevant:

> *"[if] you can demonstrate an apparent causal relationship between television violence and children's violent behaviour under laboratory conditions, does this mean that such a relationship will also exist in the complex and varying social contexts in which children actually watch television?"* Le Voi (2001).

Qualitative research approaches differ in a number of ways from quantitative approaches. Qualitative research supports the view that different people will have differing perspectives, rather than one fixed understanding of an event or situation. Qualitative approaches tend to use inductive reasoning and a more 'bottom up' approach. Unlike in quantitative research, qualitative researchers often do not attempt generalisations beyond the specific population being researched.

Qualitative research methods have been used to understand human behaviours such as social interaction, belief systems, knowledge, behaviours and attitudes of the research subjects in their natural environment, and can include educational research environments.

It has been argued that a key advantage of qualitative research is the provision of rich understandings of small research populations, or case studies involving one or a few participants. Hypotheses grounded in qualitative data can help construct theories relating to such a target group (Creswell, 2009). However, as indicated above, such outcomes may not be generalizable to a wider target population. Fraenkel & Wallen (2008) observed that:

> *"Quantitative researchers want to establish generalizations that transcend the immediate situation or particular setting. Qualitative researchers, on the other hand, often do not even try to generalize beyond the particular situation, but may leave it to the reader to assess applicability. When they do generalize, their generalizations are usually very limited in scope."*
> Fraenkel & Wallen (2008).

Opponents of qualitative research argue that its methods may offer explanations that are not based on sound evidence, possibly putting into question the validity of qualitative research results. Silverman (2006) warns of the danger of 'anecdotalism' where a particularly fascinating observation, which is not typical of the subject group population, may colour the wider interpretation of results (Silverman, 2006, pp 47).

Not all researchers subscribe to a binary view of competing quantitative and qualitative research perspectives. Glaser & Strauss (1967) observed:

> *"There is no fundamental clash between the purposes and capacities of qualitative and quantitative methods or data. What clash there is concerns the primacy of emphasis on verification or generation of theory - to which heated discussions on qualitative versus quantitative data have been linked historically [...] We believe that each form of data is useful for both verification and generation of theory, whatever the primacy of the emphasis."* Glaser & Strauss (1967, p17-18).

Following Glaser & Strauss it is possible to combine quantitative and qualitative approaches in what is termed as 'mixed methods' combining for example, the outcomes of an analysis of quantitative data using a statistical framework of measurement with the outcomes of an analysis of data derived using an appropriate qualitative approach.

Greene et al., (1989) suggest that a mixed methods approach can help to improve the validity of the research by reducing the influence of bias that may originate with the method or the researcher.

Expanding the scope of the research inquiry to accommodate mixed methods can lead to a richer understanding of the research subject and outcomes. This was seen as a major advantage in the present research, given the low participant numbers and the highly individual nature of each child taking part in the research studies.

Three approaches which are generally considered as 'mixed methods' were considered for their applicability to the current research. These are described briefly next.

Grounded Theory

A research approach often used to analyse human behaviour is *grounded theory*. Grounded theory, originally put forward by Glaser and Strauss (1967), provides a way of analysing a wide range of qualitative and quantitative data types, including interview transcripts, video and audio footage and field notes. Grounded theory differs from other established methods by iteratively analysing data to create a theory grounded in the findings of the research, rather than testing pre-ordained hypotheses.

The data gathered using a grounded theory approach are identified and grouped together as a collection of similar events or behaviours (known as categories) using an analytical process called 'data coding' (or just coding). Data coding typically begins soon after an initial interview or period of observation is completed. This initial coding (known as open coding) is the act of breaking down new or raw data into sections to allow the researcher to interpret their meanings.

The act of data coding, continues after open coding has been completed, and on through the data collection and analysis process until the process reaches a state of data saturation, where further data gathering does not reveal any new insights. Initially, textual data can be taken from for example, observations or interviews that are then analysed and coded using an open coding method. Research memos can subsequently be produced describing a concept derived from the data being analysed. A continual process of questioning and comparing the data, (which Glaser and Strauss (1967) call the constant comparative method) is carried out by the researcher on the emergent data categories. Such categories can be grouped by the researcher to support deeper insights into the subject area. Data analysis of categories and group categories are carried out as parallel rather than serial tasks following a process of refinement until the analysis terminates (Glaser and Strauss, 1967, p. 105-113).

In the process of data coding described above, a technique called 'theoretical sampling' is used to identify and gather new data and new perspectives from the outcomes of previous data gathering cycles. By comparing different sources of data within the same research study, it is possible to use triangulation to develop a richer understanding of the problem area. The decisions made by the researcher during theoretical sampling are influenced by the emerging theory rather than being based on a preconceived theoretical framework (Glaser & Strauss, 1967, p 45).

Grounded theory is not without its critics. Opponents argue that grounded theory's process of transcription and iterative data analysis is very time consuming and complicated (Bryman, 2008, p. 549). The complex nature of grounded theory, considered by some to be a subjective process, relies on the skill and experience

of the researcher, which makes it a potentially difficult method for new researchers to use (Carvalho et al., 2003). Some critics suggest that many researchers who espouse the use of grounded theory are in fact using it as a data coding procedure rather than for theory development (Braun & Clarke, 2006; Bryman, 2008, p. 549).

Action Research

Action Research is a flexible and adaptive mixed methods approach that involves all those in the research (the researcher, the participants and research supporters) as having equal voice and influence (McNiff & Whitehead, 2009, pp. 11-21). The approach was originated by Lewin (1946) and was adopted initially within the development of management practice. It later found wide application within teaching and educational contexts. The prime emphasis of action research is to improve the practice of those involved in the research (e.g. in management development). Action research aims to achieve this within an idealistic framework that promotes emancipation of all individuals taking part in the research, attempting to equalize power differentials in social groups, encourage open and free communication between individuals and allow individuals to be unconstrained by power and status (Somekh & Zeichner, 2009). For example, Reason & Bradbury (2001) argue that:

> *"The primary purpose of action research is not to produce academic theories based on action; nor is it to produce theories about action; nor is it to produce theoretical or empirical knowledge that can be applied to action; it is to liberate the human body, mind and spirit in the search for a better, freer world".* Reason & Bradbury (2001, p. 5)

From a practical perspective, improvement in practice is sought using a cyclical, iterative, systematised methodology based upon a sequence of action (intervention), assessment of, and reflection on, the consequences of such action, followed by further planned adjustments and improvements. Action research is frequently adopted in studies in educational contexts involving small research populations. However, critics of action research argue that the focus on smaller populations (for example, a target group of one class of children) mean that the findings may not be generalizable to a wider population. It has also been argued that application of an action research methodology is not always sufficiently rigorous (Baskerville & Wood-Harper, 1996). A further criticism sometimes levelled is that data collection or data interpretation may be biased towards the result that practitioners wish to achieve (Fraenkel & Wallen, 2008, pp 595).

Formative Experimental approach

Formative Experimental approaches are used in educational settings to investigate and improve pedagogical methods by highlighting aspects that inhibit or enhance the effectiveness of the subject area. Formative experiments are conducted in authentic teaching contexts and are primarily focused on an intervention, with the aim of improving its effectiveness. Formative experimental practitioners attempt to achieve the aims of such approaches by targeting specific aspects of an intervention or practice that they wish to improve. This is achieved by using an adaptive and iterative process that observes a pedagogical method, evaluates its effectiveness and then attempts to improve it (Reinking & Bradley, 2008, pp. 17-22).

The formative experimental approach does not subscribe to any one data collection or analysis method, making it methodically inclusive and flexible. For example, by combining quantitative and qualitative data taken from observations of a child's social and non-verbal communication it may be possible to construct a richer understanding of outcomes and relationships that may influence an intervention. Results from formative experimental research can also help to develop generalizable understandings and help to inform policy makers and practitioners about the effectiveness of new and established pedagogical approaches (Reinking and Bradley, 2008, pp. 34-35).

It has been argued that formative experiments have some similarities with action research (Reason& Bradley, 2001). Both approaches when applied to educational contexts, make use of iterative trials to improve the educational outcome of for example, some teaching intervention. Both approaches also consider the researcher, children and teachers to be part of the research. However, in formative experimental approaches, the explicit ideology of action research is absent. The perceived role of teachers can also differ; in formative experimental research, teachers are considered subject experts providing valuable insights into the interventions used and the participants taking part; in action research, teachers are perceived as an integral part of the research team. However in either case the support teachers' knowledge and experiences can be used to inform the research and its interpretation.

In the present research study a formative experimental approach within the mixed methods category was adopted, as this was considered to be most appropriate to the research envisaged, including aspects of the research study management by the researcher. The major experimental phases of the work are detailed in the pilot

study and main study chapters (Chapters 5 and 6). The pilot study comprised a 'proof of concept' phase to allow a full CAPE system to be envisioned, designed, developed and implemented for use in the following main study phase. The data acquisition and processing methods for each major phase of the experimental programme are described next.

3.3. Data acquisition methods

Three data acquisition methods were identified, considered appropriate to the anticipated research and subsequently used for that purpose. One area of particular concern during the experimental phases was to ensure that data which could be captured by a single method was backed up by other methods given that the study sessions were of an unrepeatable nature. The data acquisition methods adopted included:

- Observation of child and teacher activities during study sessions

- Audio-video data capture of child and teacher activities during study sessions

- Interviews with teachers subsequent to study sessions

Observation

Observation can be the major data acquisition method used in an investigation. As an example, observation of the arrangements for children arriving at or leaving school could include the mode of transport used and the experiences of adults escorting the children. Such observations would be likely to include both quantitative and qualitative data.

Where the participant's behaviour is important to the line of enquiry, observation may enable the researcher to build significantly on the present understanding of an area of study. This is especially important when participants do not have the understanding or language to articulate their views in, for example, an interview. This is the case in this research investigation with regard to the participating children.

Observation has some potential drawbacks. For example, observational data can be time consuming to collect and subsequently analyse. In any observational study it is a prerequisite that the researcher will be familiar with behaviours typically exhibited within the context of the research area. A lack of fundamental understanding could otherwise lead to incorrect assumptions about the behaviour being observed (Corbin & Strauss, 2008, p. 27-32).

Observations were an important research method in this investigation, given the severely restricted ability of child participants to articulate their experiences and perceptions to their teachers or the researcher. In this research, the researcher's field notes were supplemented by audio-visual recordings. These allowed session activities to be replayed, behaviours and incidents to be detected by repeat viewings and reflected upon after the live event, then subsequent analysis to be undertaken.

Field notes were used extensively during both the pilot and main studies to record details of each child's interaction with CAPE and with the supporting teacher. Such notes provided a backup to the audio-visual recordings, as well as noting additional information. For example, notes were made of observations relating to child / teacher social interaction and joint attention. Observation data was captured in field notes and an audio-video capture approach and was analysed together with field notes using software analysis tools which are described next.

Audio-video data capture

Audio and video recording of all CAPE learning activities was undertaken using a compact webcam that also incorporated a small audio microphone. Several options were considered to support the extraction of data from each study's video recordings. Requirements included the:

- ability to create transcripts of video and audio sources

- quick and efficient assignation of codes using data coding

- collection of quantitative data

After trialling various software packages it was concluded that *Focus 3* multi-media analysis software fully met all quantitative and qualitative needs of this research, and it was subsequently adopted. *Focus 3* originated from the Open University's prior collaboration with the BBC. It allowed the researcher to code children's behaviours and interactions with the CAPE system from audio-visual recordings. Using Focus 3 the researcher was able to create transcripts of video and audio sources and then analyse the data using data coding methods (see Section 3.2).

Using Focus 3 in this research enabled quantitative and qualitative data to be collected from video recordings of both pilot and main study sessions. Quantitative data included timing of events, counts of the number of times the child correctly removed the symbol from the RFID reader (described here as 'symbol tidy'), the correctly selected symbols and the number of times the support teacher had to prompt the child to respond or select a symbol within an activity. Qualitative data was based on descriptive codes assigned to events. The data was collected for later analysis (described later in Section 3.5). Figure 3.1 presents an annotated example of the data analysis process from the pilot study. The key features shown in Figure 3.1 are annotated, and then described briefly in Table 3.1.
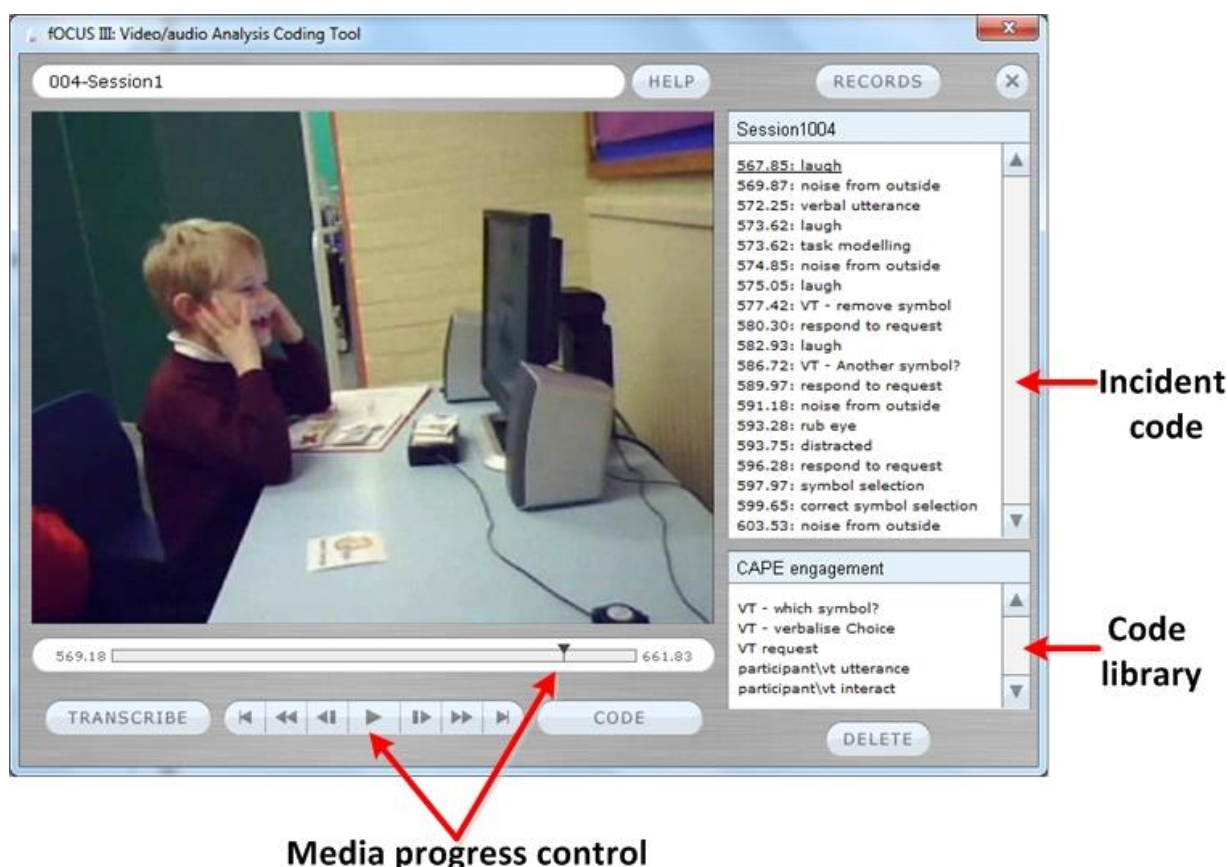
Figure 3.1: The Focus 3 data-coding screen

Table 3.1: Descriptions of annotations in Figure 3.1

Function	Description
Media progress control	Position within the video or audio content is controlled by the function buttons (similar in appearance to those found on domestic video recorders).
Incident code	These codes represent initial or open coding of the data. The codes are linked to a specific time event (as shown in Figure 3.1).
Coding library	The coding library contains codes that have been preconfigured by the researcher. New codes can also be added to the library during the coding process.

Data derived from audio-video recordings can be analysed using one or more collections of codes created by the researcher (Figure 3.1, code library) in Focus 3. Observed activities and behaviours were coded and referenced to study session time lines.

Data coded in Focus 3 are saved by the application to text files in ASCII format, allowing data to be imported into other applications, such as Microsoft Excel or IBM Statistical Package for the Social Sciences (SPSS) for further processing and subsequent data analysis. Data from observations were compared to data from teacher interviews (discussed next) to provide a richer understanding of the data (see Chapter 5, Section 5.3 and Chapter 6, Section 6.3).

Interviews

Interviews can be particularly useful in acquiring and collecting data relating to experiences, opinions, judgements, and significant observations. Data may relate to thoughts already residing in the mind of the interviewee, or thoughts that are formed as a direct result of prompts built into a researcher's questions. Interviews can be tightly or loosely specified, constrained and managed through adoption of an appropriate interview format. Fraenkel & Wallen (2008, p. 446-447) identify four broad types of interviews:

- Structured interviews

- Semi-structured interviews

- Unstructured interviews

- Retrospective interviews.

Structured interviews comprise a set of pre-defined questions designed and selected to cover all required aspects. All respondents answer the same questions in the same order. Structured interviews provide a high level of comparability and reduce the chance of interviewer bias, as each interviewee will have the same questions worded in the same way. This approach would be likely to constrain the discussion of emergent areas of interest that an interviewer may otherwise wish to pursue and can limit the natural flow of the interview due to its rigid structure.

In semi-structured interviews, the interviewer again specifies all aspects to be covered in advance, but may modify the sequence and exact wording of questions during the course of the interview. The advantage of this approach is that it can increase the richness of the data collected and allow the researcher to pursue

lines of interest based on the answers the respondent gives. A potential drawback is that the researcher may inadvertently omit some areas of interest if the interviewee's answers divert the interview away from its central theme. Because of the differences in questions asked of the respondents, comparisons may be less reliable than for structured interviews.

Unstructured or informal interviews may be conducted in much the same way as natural conversations, with questions emerging as a result of responses from the interviewee. In this format, the interviewer has no predefined script of questions to follow. An advantage is that the responses may better represent the interviewee's beliefs and opinions on the subject being discussed (to the extent that they are willing to reveal their thoughts on the subject matter). There is a danger that significant omissions may arise where some aspect is not raised during the course of an interview. Overall, responses to unstructured interviews are least likely to be suitable for comparison between different interviewees' responses.

In retrospective interviews the researcher discusses with the respondent past events where a significant delay between the interview and the events has occurred. The interview can be conducted as either a structured, semi-structured or an unstructured interview. A weakness of this approach is that it may provide information that does not reflect accurately the real events being studied, as all data collected in this way will be reliant on long-term memory and may be biased by current rather than contemporary opinion or perspectives.

A variance in the rate of learning improvement between children was expected over the course of the research. This suggested that teacher observations and comments of child progress should be captured as soon after a session as possible to minimize possible data loss. This was particularly important in the main

study where improvements to CAPE V2 could be implemented based on each child's progress or experiences in a session. It was felt that a semi-structured interview style complemented this approach and was subsequently adopted. Such interviews were undertaken once all teaching sessions had been completed for the day. Using a semi-structured interview approach helped to ensure that aspects that teachers considered important were fully discussed and that the best use was made of teachers' limited availability.

Retrospective interviews were conducted at the end of the programme some five weeks after the completion of the research studies to capture the support teachers' reflective and concluding viewpoints.

Teachers' experiences and perceptions were particularly valuable, given their professional expertise and their detailed knowledge and expectations of study participants. Data gathered from teacher interviews allowed the researcher to identify influences (not only positive ones) on the child's ability to learn or improve symbol communication skills. In particular, negative influences which could result in children's anxieties, or reduced motivation to take part in CAPE sessions, needed to be identified.

Teacher interviews were conducted in an informal style with interviewees allowed latitude to answer questions in their own way, whilst enabling the interviewer to explore areas of interest that would have been difficult using a more formal style (Hancock, 2002). On occasions when the researcher felt that the direction of the interview needed refocusing, or where a line of enquiry had been exhausted, the next question was offered for discussion.

Once data is acquired, a process of analysis is required. An appropriate process can be developed suitable to the objectives of the research and the type of data acquired. Data analysis methods which were considered during this research are discussed in more detail next.

3.4. Data analysis methods

Analysis of data from observations can be considered from a quantitative or a qualitative viewpoint. For example a quantitative approach can be concerned with the frequency with which a child correctly selects a symbol from a number of alternatives or the frequency or promptness with which the child interacts with a teacher. However, a qualitative approach is more suited to examining instances of, for example, social communication such as verbal output or initiation of joint attention with the support teacher. For these reasons it was necessary to use a combination of quantitative and qualitative approaches in the current research.

Such approaches are described next and include:

- Wilcoxon matched pairs non-parametric comparison test

- Spearman's rank correlation coefficient

- *Thematic analysis*

- *Critical incident technique* (CIT)

Wilcoxon matched pairs test

The Wilcoxon matched pairs test is a non-parametric statistical measure used to find the significance between two variables. To achieve this the measure uses the p-value and the z standard test statistical methods to test for significance between two variables.

The p-value is based on a two-hypothesis model. One hypothesis is neutral (the null or H_O hypothesis) and the other is the hypothesis being tested. The p value represents the probability of getting the same result in both hypotheses. Where p values are less than the previously decided threshold (5% or 1%) then the null hypothesis can be rejected and the test hypothesis accepted (Thisted, 1998). The z score (or standard score) compares scores from two different distributions to show how many standard deviations the result is from the mean of the distribution being analysed (Hinton, 2004, p26). In addition results from Wilcoxon signed ranks test also provide the median (or Mdn) of each of the two data sets and the r value which is derived from the z score divided by the square root of the number of data items analysed (known as N).

The aim of the pilot study was to measure the effectiveness of two voice type conditions. The Wilcoxon matched pairs test proved to be a useful way of measuring quantitative data resulting from investigations in the pilot study.

Spearman's rank correlation coefficient

The Spearman's rank correlation is a nonparametric statistical measure that enables researchers to compare two sets of data to assess the relationship between them. The Spearman's rank correlation makes use of the p-value and Spearman's rank correlation coefficient (known as r_s). r_s is used to assesses the

relationship between two variables and is expressed as either a positive, value, predicting a positive increase, or a negative value, suggesting a decline in one variable compared to another. If none of the values are repeated then it is possible for the value of r_s to be either +1 or -1 (Siegel & Castellan, 1988, p.235-242). In addition, results from Spearman's rank correlation coefficient also express the median of the data set for each of the two comparisons and the Interquartile range (or IQR) to show the range of results in the first and third quarters of the data set.

Thematic Analysis

Thematic Analysis is a qualitative approach that enables a researcher to identify important emergent themes in data that help to describe the phenomenon (Daly, et al., 1997). A theme can be defined in terms of observed patterns in the data being analysed, for example originating from directly observed behaviours or from interviewee statements (Joffe & Yardley, 2004).

Thematic analysis provides a structured and flexible approach (Braun & Clarke, 2006). Thematic analysis also allows the researcher to pre-define or discover emergent collections of coded data known as categories (Saldana, 2009, p. 36). Saldana observes that

"codes are essence-capturing and essential elements of the research
story that, when clustered together according to similarity and regularity –
a pattern – they actively facilitate the development of categories and thus
analysis of their connections" (Saldana, 2009, p. 8)

Categories can later be used to identify themes from the underlying data (Guest, 2012, p. 17). In this way a theme can be considered as the collective meaning of the data as it relates to the research questions being investigated (Braun & Clarke, 2013) or as Morse (2008) describes themes as

"the meaningful "essence" that runs through the data […] the basic topic that the narrative is about overall" Morse (2008)

Braun & Clarke (2006) identified six primary phases associated with thematic analysis (Figure 3.2).
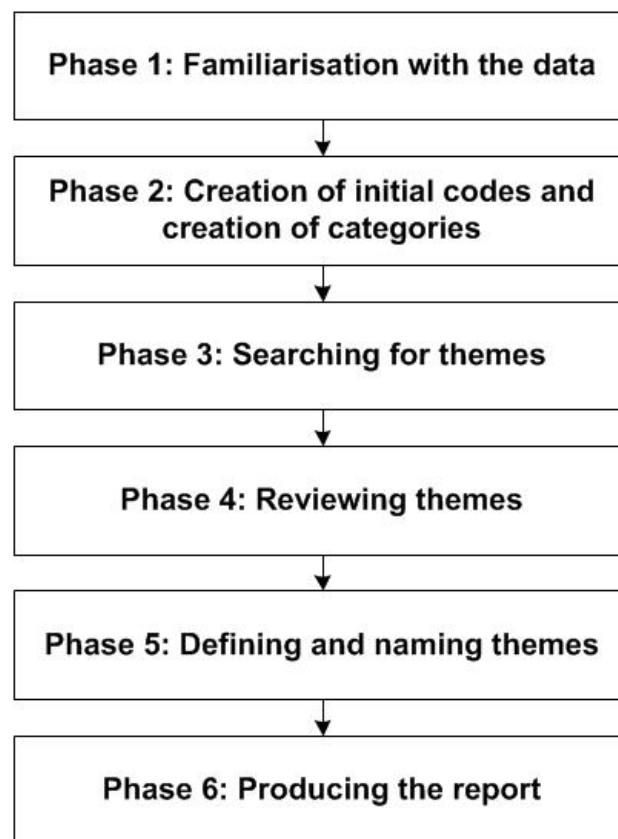
Figure 3.2: Thematic analysis phases (adapted from Braun and Clarke, 2006).

The thematic analysis process shown in Figure 3.2 and defined by Braun and Clarke (2006) was considered an appropriate methodology for the analysis of the audio-video data obtained in the pilot and main study investigations, and was

accordingly adopted. Implementation followed Braun and Clarke's phases as follows:

1. Familiarisation with data: The audio-video data was transcribed, then studied to provide an initial understanding and familiarisation with the data overall.

2. Creation of initial codes and creation of categories: A first pass at open coding was attempted using Focus 3's in-built coding tools (see Table 3.1 and Figure 3.1). The method consisted of linking descriptive labels or codes to the data to highlight specific behaviours or events that were of particular interest. These codes were later compared and scrutinised to see if one or more codes could be grouped together to categorise aspects of the data of relevance to the research. See Appendix O for an example of the initial stages of thematic data coding.

3. Searching for themes: Trial associations of coded data in categories enabled themes to be recognised and named. These themes represent the collective meaning of the codes and categories that underpin them. For example, the collection of categories and associated with a children's ability to choose symbols from a PECS folder may result in a theme called "*Visual scanning of symbols increased selection accuracy*" which describes their method of selection.

4. Reviewing themes: An iterative process was used to compare data from later sessions with earlier ones (known as a 'constant comparative' approach) to enable new themes to emerge from the data and for existing ones, where appropriate, to be discarded if they proved not to develop into primary themes in later analysis. These primary themes represent the

concise and final meaning of the data as it relates to the research

question(s) Additional codes were created as the need for them became

apparent. This process enabled the researcher to create a more detailed (or

richer) understanding of the data as a whole.

5. Defining and naming themes: each theme was reviewed and appropriate

    names created for each of the themes to provide a way of describing the

    meaning of the theme. By defining the themes it was also possible to

    compare and contrast the themes to understand how they relate to each

    other to provide a rich understanding of the data.

6. Producing reports: Identifying themes and their relation to each other in

    stages 2 to 5 enabled a research results to be reported in Chapters 5 and 6

    of this thesis.

Critical Incident Technique

Data obtained from observations (whether audio/video recorded or logged note

form) can be analysed using the *Critical Incident Technique*. In this technique, the

researcher seeks and identifies 'critical incidents' (or events) that may otherwise

be missed (Gremler, 2004).

Flanagan (1954) defines a critical incident (described by Flanagan as an act) as:

> *"any observable human activity that is sufficiently complete in itself to*
>
> *permit inferences and predictions to be made about the person*
>
> *performing the act. To be critical, an incident must occur in a situation*
>
> *where the purpose or intent of the act seems fairly clear to the observer*
>
> *and where its consequences are sufficiently definite to leave little doubt*
>
> *concerning its effects"* Flanagan (1954, p 327).

Critical incident technique relies on the principle that observational data will only be collected by 'knowledgeable' observers. Flanagan (1954) suggests that the researcher must always begin with an understanding of the target population, taking note of appropriate principles of human behaviour. Incidents need not be radical or extraordinary for them to be 'critical'; but they should be judged to be of key significance in some way to the research being conducted.

Flanagan (1954) specified a five-stage process to prepare for an investigation based upon critical incident technique. A part of this process is to identify a broad set of categories that are related to the intended research objectives to help classify the critical incidents, known as a frame of reference (Hughes, 2007). The process suggests that the researcher should develop an understanding for the importance of critical incidents in the research by developing a frame of reference of the data (Edvardsson & Roos, 2001). This broad set of broad categories are used to classify emerging critical incidents that relate to the research questions being investigated (Hughes, 2007). For example an element of the frame of reference may be 'Symbol selection' and may result in two main critical incident categories called 'unaided symbol selections' and 'aided symbol selections'.

Critical incidents can then be grouped into categories to help describe, summarize and develop an understanding of the data (Gremler, 2004). This process is similar in approach to category creation in thematic analysis. However, critical incident technique uses the data to describe specific important events in the research that each signify a point at which a change in behaviour is identified. The process was found to be compatible with other approaches adopted in this investigation, allowing critical incident technique to be incorporated within the research methodology.

During the analysis of the audio-video data, critical incident technique was implemented by searching for and identifying critical incidents that could 'flag' significant changes in children's behaviour, their learning or their use of the CAPE system. Particular note was taken of critical incidents that could be related to changes in behaviour, particularly those that followed changes to the learning intervention; for example, a child's ability to communicate using symbols might improve or decline when they are introduced to picture or digit symbols to answer simple counting tasks.

3.5. Overview of chosen approaches for the research

An overview of the chosen approaches used in the pilot and the main study is provided next (see also Figure 3.3), with full explanations of the approaches provided at their point of use (see Chapter 5, Section 5.2 and Chapter 6, Section 6.2).

To understand the approaches used, it is necessary to refer again to the various phases of this research study. Brief descriptions are included to support the rationalisation of the methods adopted.

The pilot study phase of the research using CAPE V1 sought to establish 'proof of concept' and point the way towards the design for a final CAPE system (CAPE V2) in which children affected by autism would be positively motivated to engage in learning activities within the CAPE environment. The activities were to be led primarily by the computer-based virtual tutor, with the additional support of the human teacher. One fundamental design option needing resolution was whether the virtual tutor should use a natural recorded (describe here as digitised), or a

synthetic recorded voice (see Chapter 5, Section 5.2). Resolving this issue was a specific objective of the activities within the pilot study phase.

Gauging children's reaction to each voice variant with a small population in the pilot study required careful consideration. As indicated earlier in this chapter the pilot study design was modelled on a 'within-participant' approach to ensure the best statistical use of the small subject population available (see Figure 3.3, point 1).

In the main study, a refined version of CAPE (CAPE V2) was to be tested to evaluate its use as a teaching tool for symbol communication. The selection of an appropriate research method here was based on the aims of the research and constraints from the environment and participant needs. The main study aim was to investigate to what extent a virtual tutor-led PECS CAL system could support the development of communication skills in children with autism (see Chapter 1, Section 1.3). This suggested that the main study would need to be conducted in an authentic teaching environment (as was also the case for the pilot study).

To provide a symbol communication teaching tool for the target population it was important to consider research approaches that enabled CAPE to be fine-tuned to support each participant's needs, while also conforming to the host school's teaching practices. The main study achieved this by using an iterative method of observation and assessment of each child's needs on a per-session basis. This was immediately followed by the adaption of the intervention to better support the child's needs, where appropriate.
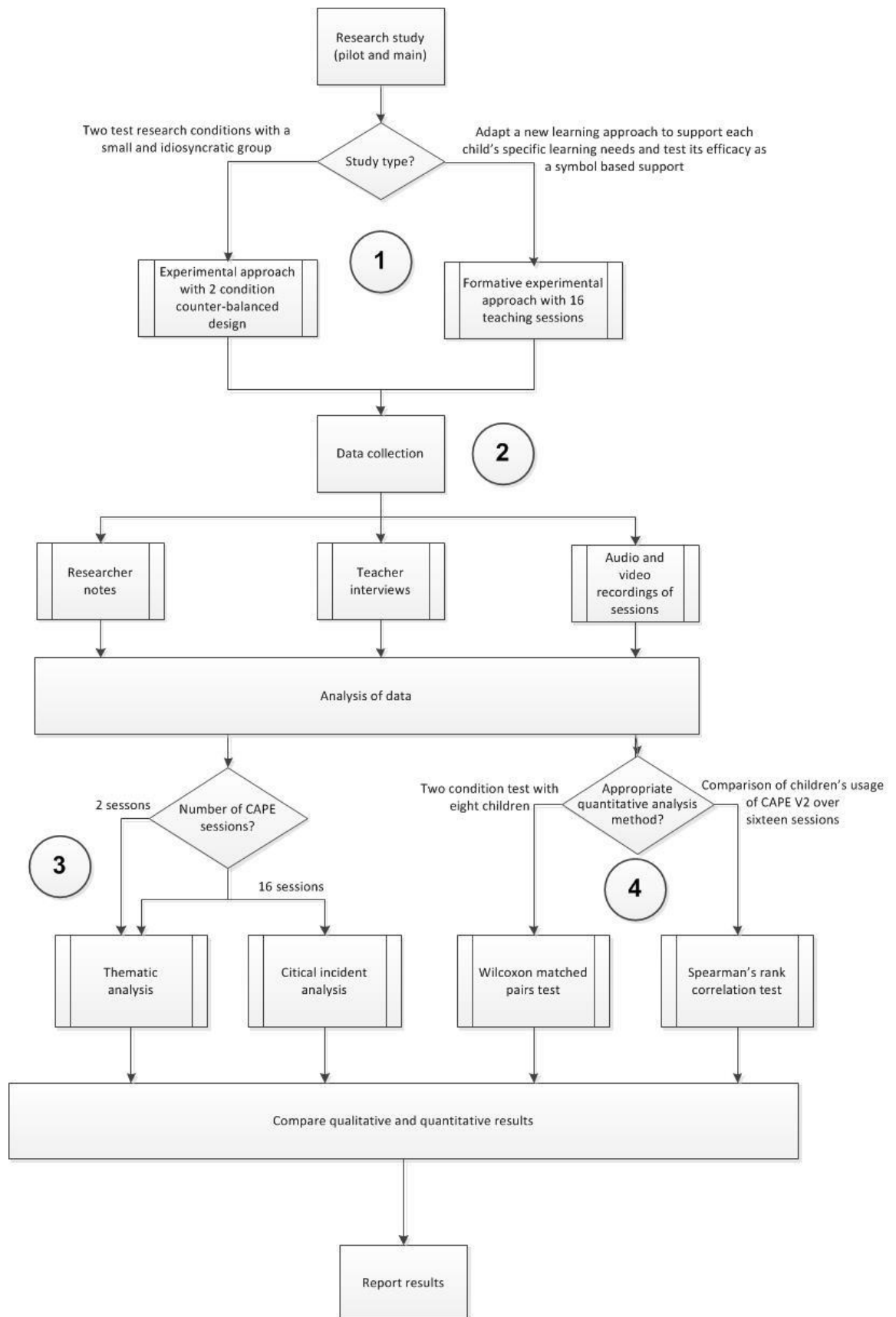
Figure 3.3: Process flow representation of adopted research methods for the pilot and main studies

The main study design required the use of a mixed methods approach with a combination of quantitative and qualitative data being collected (see Figure 3.3, point 3, 4 and Figure 3.4). In the pilot study the researcher chose to restrict qualitative analysis to a thematic approach because it was likely that few if any critical incidents would be identified in such a short time (two sessions with a maximum of ten minutes per session). However, in the main study a mixed qualitative approach was more appropriate as it allowed the researcher to identify behaviour themes and identify critical incidents responsible for influencing change over a much longer research period (sixteen session each lasting a maximum of ten minutes).

Quantitative analyses undertaken in the pilot and the main study required selection of appropriate statistical techniques suitable for the size of the research population and the variation within it (see Figure 3.3, point 4). The research population in these cases was small (eight children in the pilot and five children in the main study) invalidating parametric statistical analysis approaches that can be appropriate when the research population is sufficiently large and normal distributions apply (Hinton, 2004, p. 210). Non-parametric approaches are more appropriate to the small research populations available in this research.

For the pilot study, the quantitative data were analysed statistically using Wilcoxon matched pairs non-parametric comparison tests (Chapter 5, Section 5.3 and Figure 3.3, point 4). The Wilcoxon matched pairs test has been shown to be a valid way of establishing the statistical significance of outcomes and the resulting inferences (Siegel and Castellan, 1988).

One objective of the main study was to measure the change in a child's ability to carry out counting tasks using RFID-enabled PECS symbols. Statistical analysis of data from five non-verbal children with varying levels of counting skill over sixteen sessions was analysed using the (non-parametric) Spearman's rank correlation (see Figure 3.3 point 4). This test was chosen as it has been shown to be helpful in establishing the level of correlation between two ranked variables (for example the association between the number of correct symbol selections a child makes and the number of study sessions they experienced) with small idiosyncratic groups. To measure quantitative data resulting from children's interactions with CAPE V2 the Spearman's rank correlation coefficient was used (Siegel and Castellan, 1988, pp. 235-244).

The research approach adopted for the pilot and the main studies included a mixed qualitative analysis approach. This approach combined thematic analysis and critical incident technique as a way of building a detailed understanding of the children's behaviour and experiences during CAPE use (see Figure 3.4). This combined approach was broken down into three primary stages:

1. Familiarization with data

2. Data analysis

3. Report on study findings

The researcher became familiar with the data by reading through and noting important observations within the data from a thematic perspective. Becoming familiar with the data also helped the researcher to establish a critical incident frame of reference that helped to highlight critical incidents that were perceived to

97

be significant. This process was repeated a number of times until all possible candidate themes and critical incidents had been identified.

Data analysis of candidate themes and critical incidents was carried out as a parallel process. Data taken from thematic note taking and transcribed observation data were analysed and emergent or initial thematic codes were documented. The initial thematic codes were grouped into categories and analysis of the categories was used to develop theme descriptions that were considered to summarize the theme description. The themes were reviewed to aid in the development of promising themes and removal of less promising ones. For example, an early theme 'correct symbol selection increased over sessions' was replaced by the more accurate 'visual scanning of symbols increased selection accuracy' which helped to describe the overall reasons for the increasing accuracy of children's symbol selection.

At the same time, a collection of critical incident categories (known as a frame of reference) was developed, with headings that embody the meaning of the critical incidents and relate to the intended use of the data (Hughes, 2007). Developing the critical incident frame of reference allowed emergent critical incidents to be categorised to create a rich understanding of the critical incidents. The results of categorisation of the critical incidents were then reviewed and refined.

Analysis of data using thematic analysis and critical incident technique was repeated until no further improvement in the understanding of the data from these two perspectives was possible. Once this stage was reached, it was possible to define primary themes and critical incidents in the data. These results were then reported in the appropriate research chapter in this thesis (see Chapters 5 and 6).
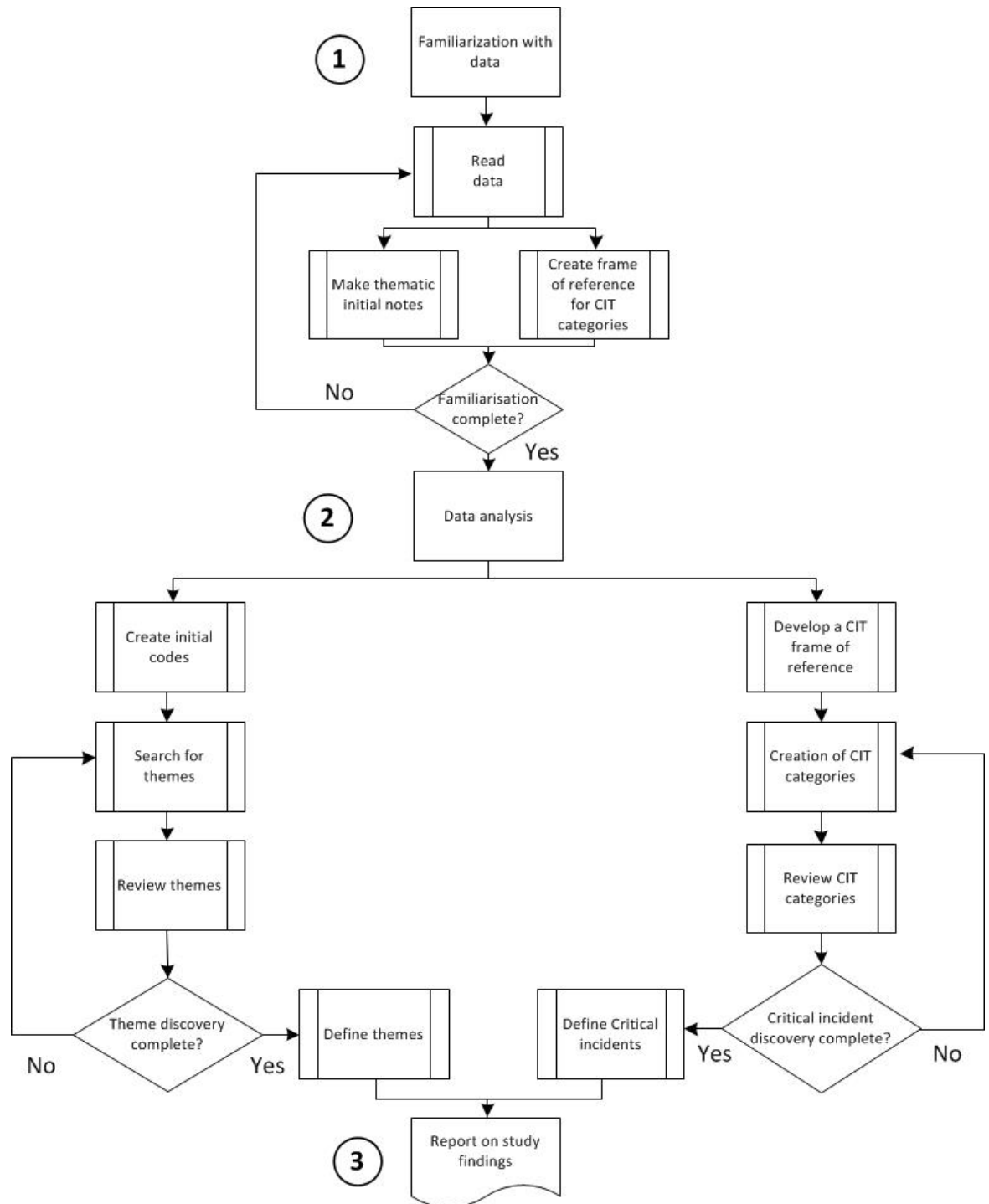
Figure 3.4: Process flow representation of adopted qualitative approach

3.6. Ethical considerations and safeguards

Research with vulnerable children presents ethical considerations and a requirement for appropriate safeguards to protect them from harm and ensure their rights are protected. The participants in this research included young, vulnerable children. From an ethical viewpoint, and in order to meet The Open University's requirements, appropriate safeguards and protocols were implemented to ensure the rights of children, parents and guardians were protected. The investigation was defined and administered in line with approved guidance relating to children's participation in research issued by: the British Educational Research Association (BERA); the British Psychological Society (BPS); and the Open University ethical guidelines for research with human participants (HPMEC, 2006). The research design and its adopted safeguards were also subject to ethical approval by the Open University's Human Participants and Materials Ethics Committee (approval reference HPMEC/07/#293/1).

A child's inclusion in the research was strictly conditional on the child's parent's or guardian's consent. Appendix B depicts the parental consent forms adopted. As the children were unable to articulate their wishes directly it was imperative that parents, guardians and teaching staff with loco parentis responsibility were fully informed of the research aims, research design and the rights of children in their care who were taking part in the research. Therefore, the researcher provided the host school with a detailed description of the research design and the ethical safeguards being adopted and received acceptance of the proposed design and safeguards from the host school before research was allowed to proceed.

The researcher ensured that parents and guardians of each child were informed that participation was conditional on their agreement and that they could withdraw their child from the study at any time. The researcher undertook, and agreed with teachers, to halt any session where there was any indication of a child's distress, or unwillingness to continue a session. Continued participation was conditional on the child's clear indication of comfort to continue.

Ethical practices included the following:

- Child participants were always accompanied by their teacher, in line with the school's and the Local Educational Authority guidelines.

- The researcher accepted the authority of the host school's teaching staff and was subject to its supervision at all times during his visits to the school. Also, the researcher did not attempt to direct the teachers or to interact with any child or group of children.

- Prior to the study, the researcher undertook an enhanced Criminal Record Bureau (CRB) check as required by UK government law for people working with children.

- All changes to learning schedules were introduced in a controlled way and only after discussion and agreement with the teaching staff.

- Data collected during the study were treated as confidential. All data were stored in a locked cabinet when not in use. Electronic data such as video and audio recordings were stored in an encrypted disk partition.

- The names of individuals discussed in this research have been changed to protect individuals' anonymity. This allowed convenient, but protected

reference to individual children and their teachers in this thesis. Participant aliases are listed in the pilot and main study chapters (Chapters 5 and 6).

3.7. Summary

This chapter introduced the rationale for the adoption of research methods that were deemed appropriate for this research.

During the design of the research, quantitative and qualitative research methods were considered. The selection of appropriate research methods was based on the aims of the research and the constraints of the children who were to take part in the study.

The aims of the research suggested that two major classroom based studies should be undertaken. A pilot study sought to investigate how non-verbal children with autism interacted with a prototype PECS-based learning system. This was followed by a main study that sought to improve and test a PECS-based CAL system. Review of appropriate research methods for the pilot and main studies suggested that a mix of qualitative and quantitative methods should be used.

The pilot study was conducted to establish proof of concept and also to resolve a design issue relating to two voice types. To minimize the possibility of ordering effects a two-condition counterbalanced, within-participant method was used and a mixed methods approach used to analyse the data. Quantitative data was processed using the *Wilcoxon matched pairs test,* which was chosen as the most appropriate method for establishing statistical significance of outcomes. Qualitative data was analysed using thematic analysis*.*

The main study was based on the formative experimental approach and utilised mixed data collection and analysis methods. This included testing for any significant change to each child's ability to respond and interact with the virtual tutor over time using quantitative data.

In the main study quantitative data was analysed using *Spearman's rank correlation coefficient* method. This method allowed the researcher to test for correlations between each condition and the number of sessions the child experienced. Qualitative data was analysed for critical incidents and themes associated with children's interactions with CAPE (see Figure 3.4).

The combination of qualitative and quantitative data collection and analysis in the pilot and main studies allowed the researcher to develop a rich understanding of the results and to answer the research questions set (see Chapter 1, Section 1.3). The aims of the research also influenced the design of CAPE. These influences will be discussed in more detail next.

Chapter 4: Design and development of a computer-based PECS system

4.1. Introduction

This chapter describes how the Computer Assisted Picture Exchange (CAPE) concept was designed and developed to investigate the research questions posed in Chapter 1, Section 1.3. The underlying concept was to create a computer-based, virtual tutor-led system, which mirrored the operation of a conventional Picture Exchange Communication System (PECS) normally led and managed by a human teacher.

The design and development of CAPE was not a one-off event preceding field trials, but was a three-stage process of progressive and iterative development and refinement to meet the needs of the subject groups and individuals. Various embodiments, in chronological order, are referred to as the CAPE Simulator, CAPE V1 and CAPE V2.

The chapter begins by presenting the overarching design aims and rationale, before describing the specifics of the CAPE Simulator, CAPE V1 and CAPE V2 developments and the associated rationale for the design decisions taken at each stage.

4.2. Over-arching design aims

A core principle of the design approach was to model CAPE closely, particularly from a procedural perspective, on the established Picture Exchange Communication System (PECS) pedagogy.

PECS is designed to provide a method of communication using symbols for non-verbal children with autism. It encourages children to develop and practice spontaneous communication, which may eventually lead in some cases to the development of verbal communication. Basing CAPE upon PECS pedagogy, it was believed, would build on the children's prior exposure and at least part familiarity with the PECS process, whilst also providing a framework against which improvements or drawbacks could be referenced.

In PECS, the key features include a set of inexpensive printed symbols used to facilitate communication between a child and a communication partner. The symbols are typically between 25 and 50mm in size (with some variance to accommodate the child's visual and motor skills). Each symbol represents an object, request or event that the child can select. Communication is generally achieved by the child passing one or more symbols to the communication partner. Simple sentences can be articulated by attaching appropriate symbols to a sentence board. The symbols are selected from a ring folder known as the 'PECS folder' where they are normally retained. The basic arrangement is depicted in Figure 4.1.

Figure 4.1: PECS symbol exchange (Herring et al., 2010)

The CAPE implementation was planned to retain the basic PECS features of symbols, a sentence board and a PECS folder to store the symbols.

The retention of these basic features in the design, although realised in modified forms, may be considered to be unnecessarily technically conservative, given the possibilities of alternative symbol selection using, for example, adapted computer keyboards, other off-screen input buttons, mouse clicks, touch screen taps over on-screen symbols or buttons. However, these alternatives could also introduce new and significant challenges and uncertainties to the children, whilst diverging from the central design aim. Other challenges included the need to support children in their migration to picture-based symbols that represent real world objects (similar in function to PECS symbols) and the development of a child's understanding of the relationship between the graphic image on a symbol and the onscreen representations of the symbol. It was hoped that by retaining a physical symbol approach, the children would be able to cross over from their conventional

use of PECS, to the Computer Assisted Learning (CAL) environment, albeit with the support of an attendant human teacher.

The provision of a virtual tutor who would take over the primary role of the human teacher in the conventional PECS situation was another key requirement. The virtual tutor and the environment as a whole would be designed as far as possible to provide a similar level of support and 'comfort' that would be experienced with a human teacher. To ensure that children remained motivated to engage with CAPE it was important to present visual and/or audible rewards to acknowledge a child's success used in the standard PECS. It was also important to provide appropriate visual support from the virtual tutor when the child was not successful in responding to a virtual tutor request.

It was anticipated that the communication dynamics proposed in the CAPE design would significantly change due to the introduction of a computer-based virtual tutor who would lead each CAPE session. Conventional use of PECS involves two party communication (one to one). In the CAPE environment this would change to a three party communication model with the child interacting, albeit in different ways, with the support teacher and the virtual tutor (see Figure 4.2). In the two party communication model, the support teacher (ST) acts as the sole communication partner for the child (C) (see Figures 4.1 and 4.2). In the three party communication model (also shown in Figure 4.2) the virtual tutor (VT) takes the role of the person the child will communicate with (referred to here as the primary communication partner, indicated here by the thick arrow in Figure 4.2). It was hoped that this would allow the support teacher more flexibility to observe the children's interactions, better understand their behaviour in relation to the learning

tasks, and to be more suitably 'placed' should the child be inclined towards human social interaction and joint attention (see Chapter 2, Section 2.2).
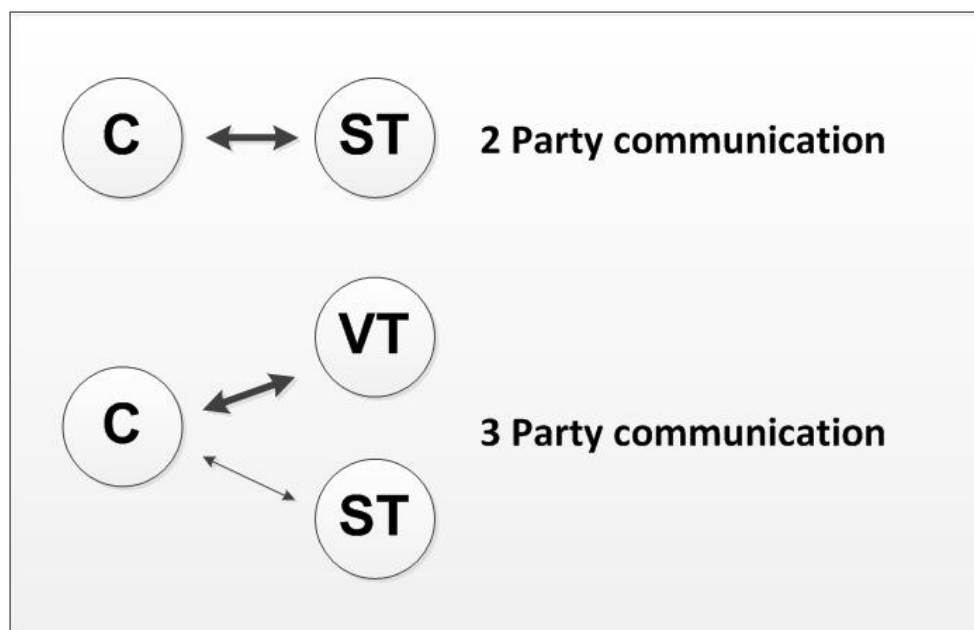
Figure 4.2: Communication models

Another design aim was to achieve the functionality required within strictly limited time constraints determined by the period allowed for this investigation. The design and development of CAPE required the testing and evaluation of different technologies and the choice of application development tools to create interactive systems. A Rapid Application Development (RAD) approach was adopted. RAD allows developers to create fully functional applications in a short development time by using an incremental development model (Pressman, 2001, p. 31). This allowed the building of a series of prototype sub-systems, which could be individually tested then subsequently integrated.

This chapter next presents an account of the technical design and development issues and solutions associated with the three specific developments. The CAPE Simulator provided an initial design, which was tested by a higher functioning child

with autism to discover how and where improvements could be made in the creation of a first classroom-ready version (CAPE V1). CAPE V1 provided the 'proof of concept' system, which was used in the pilot study investigation conducted with two groups of children in a classroom environment. CAPE V2 was the final design of CAPE that provided a flexible and adaptable CAL environment suited to a range of curriculum activities and learning, which was also trialled in a classroom environment.

4.3. The CAPE Simulator

During the conceptual design of CAPE, the researcher sought to achieve four primary objectives. These were:

- to create a child-friendly symbol placement user interface based on Radio Frequency Identification (RFID) technology

- to provide an appropriate computer application with graphical virtual tutor / child user interface and processing structure based on the conventional PECS symbol exchange process

- to create and present animated content to encourage child engagement and reward correct symbol selection

- to develop an environment in which user testing of the CAPE concept could be carried out

The above objectives were met by a process of identifying key functional requirements then developing and testing hardware and software components that made up individual sub-systems, before then testing whole system performance.

This process will be described shortly but will be better understood by an indication of the basic CAPE Simulator functionality.

The starting point for implementing the design of the CAPE Simulator was the selection of the software development toolkit that was freely available from the Center for Spoken Language Understanding (CSLU) at Oregon Health and Science University. The researcher had previously experienced this software as part of an Open University module where it had been introduced to demonstrate the potential for cybernetic interactions (Heap, 2001). The CSLU toolkit offered a number of inbuilt features such as a selection of 2D avatars that were capable of producing facial and verbal output. CSLU toolkit had also been used by other researchers to support a range of learning objectives for children with autism (Cole, 2003; Massaro & Bosseler, 2003). Figure 4.3 depicts an initial CAPE simulator arrangement.
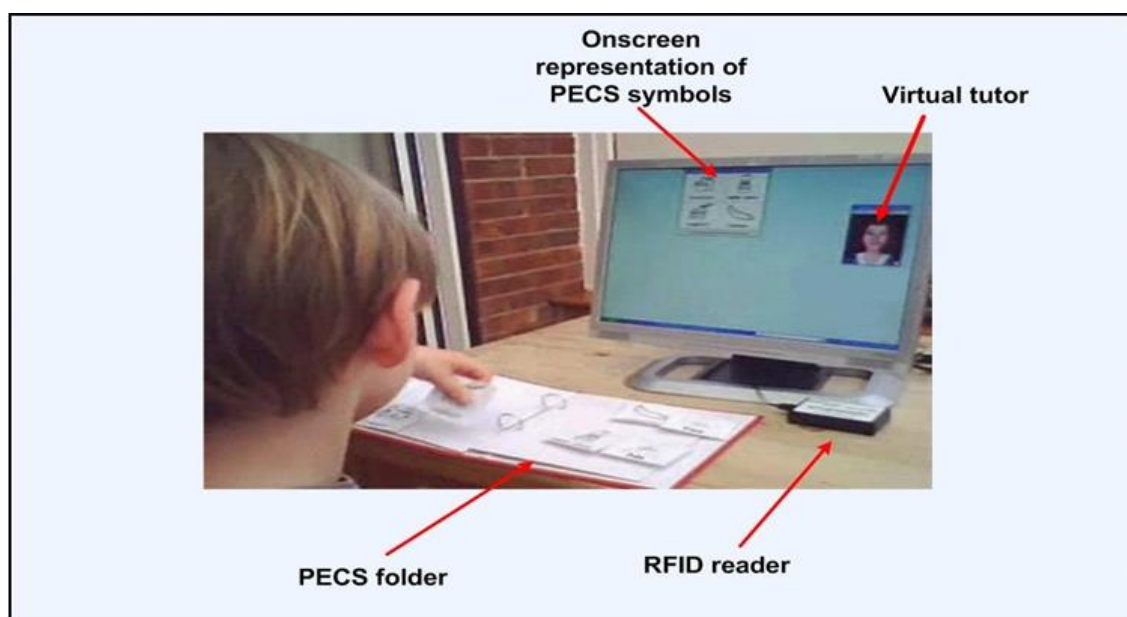
Figure 4.3: CAPE Simulator showing the virtual tutor, onscreen representation of PECS symbols, the PECS folder and the RFID reader used for symbol placement.

Selecting the virtual tutor

The CSLU toolkit included a range of avatars, which could be selected for use as a virtual tutor; Figure 4.4 shows examples. Each avatar could be assigned voice outputs either based on a synthetic voice (text to speech) or digitized natural voice. Both variants allowed avatar lip-synchronisation with uttered speech.

Reduction of facial expressions that indicate emotional state of the virtual tutor was achieved directly through the CSLU software as the CSLU toolkit facilitated emotive / expressive adjustments. A 'neutral' expressive setting could consequently be selected for the virtual tutor.
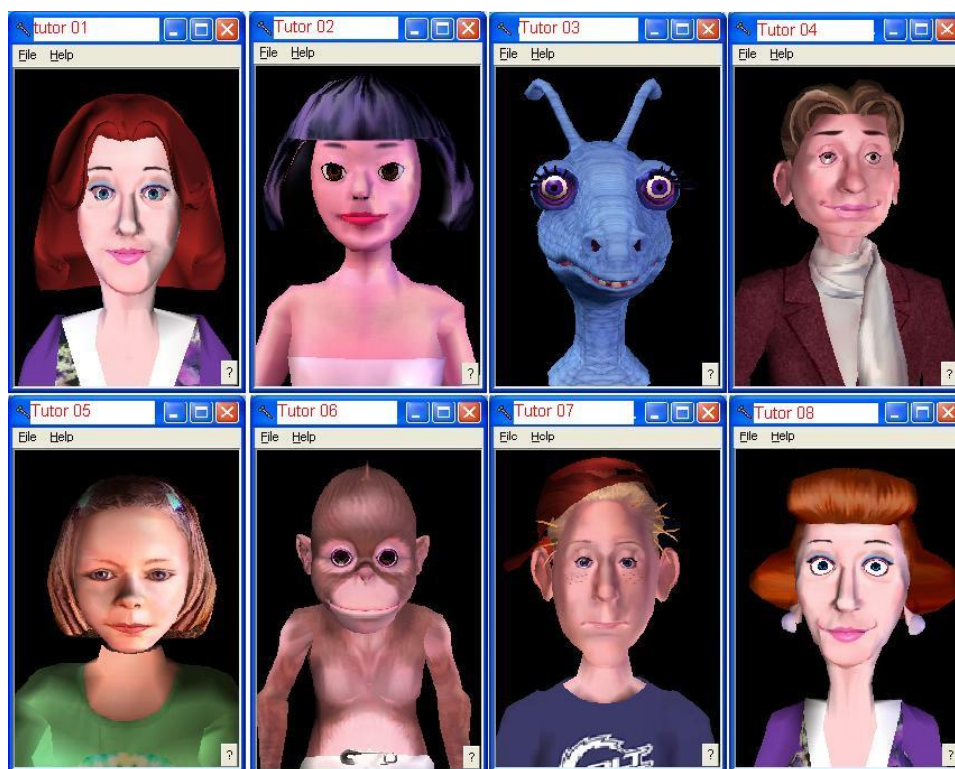
Figure 4.4: CSLU toolkit avatars (taken from CSLU Toolkit, 2002)

Tutor 1 (top left in Figure 4.4) was chosen for initial use in the CAPE Simulator (and later in CAPE V1) based on its neutrality, hopefully contrasting with the cartoon character to be used in the animated clip as a reward strategy (see later).

It was also important to choose a virtual tutor image that could be reasonably matched with either synthetic or natural voice types as this was anticipated to be an important issue to be resolved later during the pilot study (see Section 5.1, Chapter 5).

Rewards for correct symbol communication

PECS pedagogy is a behavioural approach that uses rewards to encourage children with autism to communicate using symbols. These rewards are typically received in the form of the object the child has requested in the symbol exchange (Bondy, 2012). However, the CAPE Simulator virtual tutor was not able to give real world rewards so a virtual reward was necessary. Virtual rewards were given to the child in the form of short comic animation clips.

The suitability of an animated character to the provision of reward content delivery was considered crucial to the initial enticement of children with autism to use CAPE. Therefore, design and development of the character was informed by the research and also by the views of a verbal child with autism (named here as 'Matthew'). Initially Matthew was shown images of virtual tutors provided by CSLU toolkit. Matthew selected an image depicting a monkey (see the 'Tutor 06' image in Figure 4.4). The monkey concept was further extended and adapted in hand drawn character concepts which were presented to Matthew. Matthew showed particular interest in one, subsequently referred to as "Super Monkey", which was adopted for all implementations of CAPE.

The literature suggests that cartoon characters may be better received by children with social impairments such as autism compared to content showing characters who have a realistic representation (Fabri, 2006). Children with autism also have

difficulty interpreting facial expressions and emotions (Siegel, 2003, p. 260; Jackson, 2002). Researchers such as Tartaro & Cassell (2008) have tackled this issue by developing computer generated avatars that limit expressive facial content (see Chapter 2, Section 2.4). This approach was adopted in the development of Super Monkey and the virtual tutor. Siegel (2003) observed that children with autism were likely to enjoy watching cartoon characters, which did not include significant facial expressions. In a similar way, cartoon characters included in animated content used in CAPE V1 and CAPE V2 (discussed later) were also designed to only express positive expressions (smiling).

To enable simple animation, Super Monkey was constructed from images depicting his arms, face, hands and body. By making slight changes iteratively to the composite Super Monkey image, it would be possible to provide the illusion of the character's movement (see Figure 4.5) when the images were viewed consecutively at speed using appropriate animation software.

Unfortunately, animation of Super Monkey was not possible with the inbuilt tools provided by the CSLU toolkit. However, advice posted by De Villiers (2005) on the CSLU forum proved useful. De Villiers (2005) indicated how an 'add-in' for QuickTime could be used with CSLU toolkit to deliver animated content where needed. This approach was adopted in the CAPE Simulator and later CAPE V1 (see Section 4.5).

The QuickTime interface proved to be robust during system testing; however, video media format was restricted to Apple's .mov format. An application was therefore required capable of converting multiple graphical still images into animated content in the .mov media standard. Suitable animation creation tools were tested. Mystic Media's Blaze Media Pro convertor was selected for this task

as it proved to be most effective in terms of ease of use and quality of animated content.

Media's Blaze Media Pro convertor was used to animate Super Monkey initially in the CAPE Simulator (and in CAPE V1 for short animations) but content creation proved to be excessively time consuming. Later, access to a commercially available animation application called Smith Micro Anime 6[©] Debut enabled video content to be created more efficiently (see Section 4.5). This software was therefore used as a replacement for Mystic Media Blaze Pro converter in the later development of CAPE Simulator and CAPE V1.
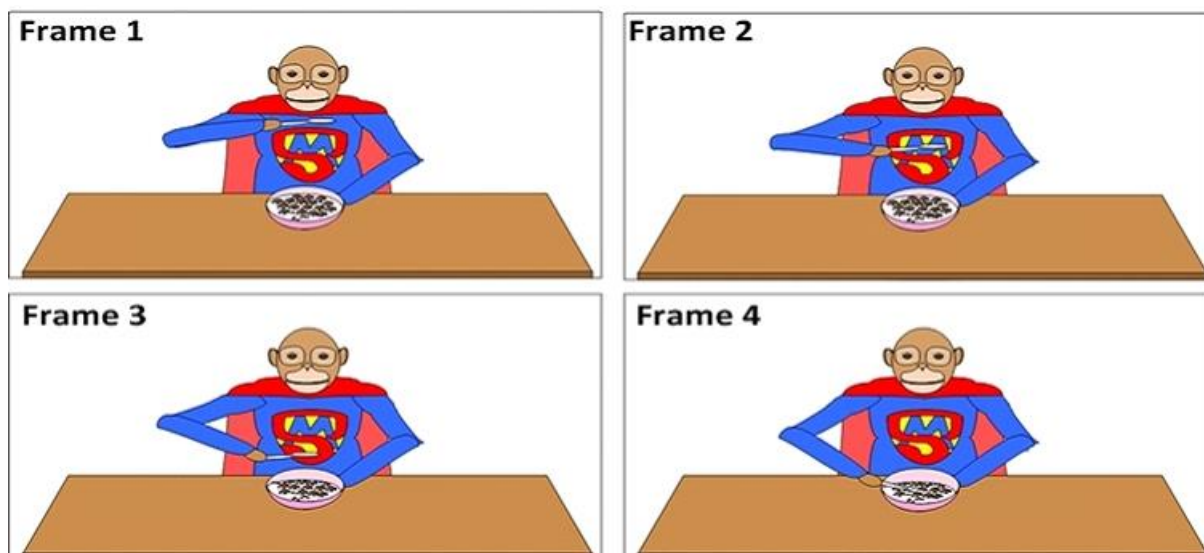
Figure 4.5: Super Monkey (stop frame) breakfast storyboard

The CAPE Simulator design focus was to demonstrate a simple task presented to a child – that of asking the child to choose a food or drink option that they thought the cartoon character 'Super Monkey' would like to receive. In this way the CAPE Simulator would enable the researcher to demonstrate system functionality to stakeholders (the school that later hosted the research studies and the supervision team) prior to the planning of the two phases of field study (pilot and main studies).

An overview of the system functionality can be gained by following the activity sequence depicted in Table 4.1.

The CSLU toolkit was used as the development environment for the CAPE Simulator and CAPE V1. The CSLU toolkit was considered a suitable starting point because it provided a number of 'out of the box' programming components which allowed relatively sophisticated design logic to be implemented, necessary to ensure the robustness of the software application (for example, through a number of appropriate error checking sub-routines).

The first step of the process involved mapping out the design and investigating the full capabilities of the CSLU software tool kit to identify how the specific functional requirements needed for this investigation could be achieved.

Important features of the CSLU toolkit included pre-created off the shelf software components that could be combined with other CSLU components, or could have their existing functions extended to add additional features to the application. These tools were utilised using 'drag-and-drop' object manipulation; an example is shown in Appendix D1. These features made more manageable the necessary software modifications and additions that were required.

Table 4.1: CAPE Simulator exemplar sequence of prompts and responses following system start-up

Event	Supporting notes	Virtual tutor dialog	Action by participating child	Response by Super Monkey
Hello sequence.	The hello sequence was used as a method of getting the child to focus their attention on CAPE at the beginning of a session.	"Hello".	Child watches.	Super Monkey gives non-verbal greeting by waving.
Task introduction by virtual tutor.	The child is introduced to the idea of responding to virtual tutor requests (described here as tasks) using symbols.	"Could you help my friend Super Monkey? He hasn't had anything to eat or drink today".	Child watches	Super Monkey visible but static.
Request symbol selection.	The child is asked to select a symbol of their choice from four food and drink choices.	"What do you think Super Monkey would like?"	Child responds with an item of food or drink.	Super Monkey is seen to be devouring the chosen item.

Event	Supporting notes	Virtual tutor dialog	Action by participating child	Response by Super Monkey
Error response: Child fails to respond within set time limit. (System waits indefinitely for a	The supporting teacher may prompt or physically guide the child to complete the task.	<No response from virtual tutor>	No response from child.	<no response from Super Monkey>
Error response: wrong symbol selected	The child has selected the wrong symbol, for example selecting Yes instead of a food or drink symbol. The child receives a 'Symbol tidy' event (described next) and once the 'symbol tidy' event is complete the request 'symbol selection' event is replayed.	"Sorry you have chosen the wrong symbol".	Child watches virtual tutor.	<No response from Super Monkey>.

117

Event	Supporting notes	Virtual tutor dialog	Action by participating child	Response by Super Monkey
Symbol tidy	The child is asked to remove the symbol from the reader and place it back in the PECS folder after each symbol selection task.	"Put the symbol in your folder"	Child takes symbol off the reader and places it in the PECS folder	\<no response from Super Monkey\>
Ask whether the child would like to continue using CAPE V1 (or instead finish the session)	The child has two options (Yes I would like to continue and No I would like to finish. If the child selects 'Yes' the system will play the symbol selection event. If the child selects 'No' the virtual tutor will play the 'goodbye' event.	"Do you want to choose another symbol?"	Child selects 'Yes' or 'No' symbol	\<no response from Super Monkey\>
Good bye	A method of showing content that allows the child to know that the CAPE session has finished.	"Thank you for helping my friend Super Monkey…Good bye."	Child watches virtual tutor and Super Monkey	Super Monkey waves goodbye

An on-screen background workspace was needed to reduce distracting on-screen clutter. Objects such as the virtual tutor, the on-screen representation of the sentence board, and the symbols selected and cartoon clips were displayed in separate windows. This resulted in the computer desktop icons and wallpaper being visible behind each fixed size window. This potential distraction was overcome by modifying and incorporating sample code (called 'background.rad') provided with the CSLU toolkit source code to create a pastel backdrop to the windows (see Appendix D, Figure D2). The result is shown in Figure 4.6.
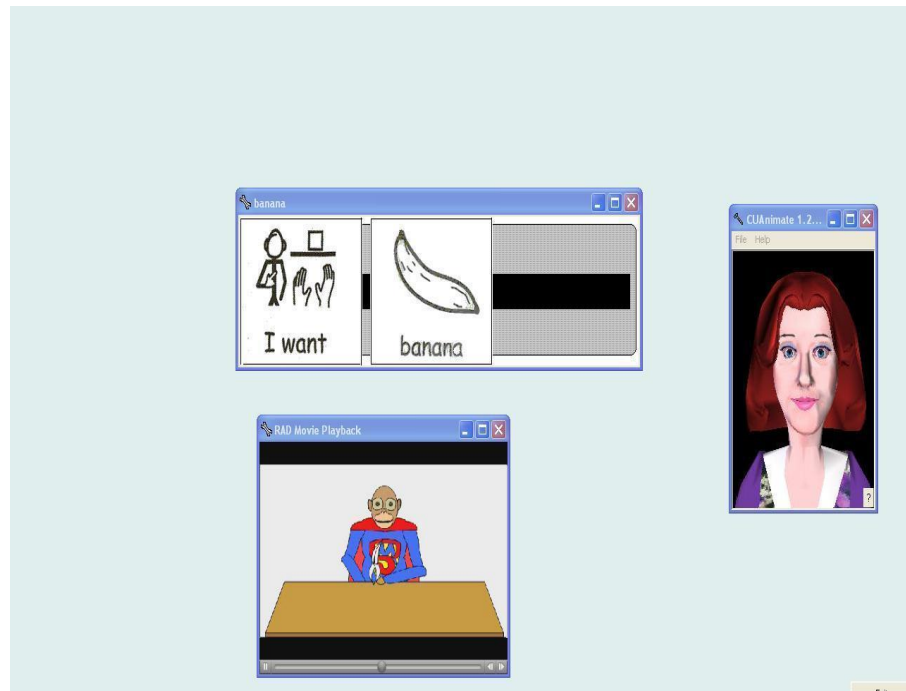
Figure 4.6: CAPE Simulator windows

Extensions to the CSLU toolkit were necessary to provide some of the required features and functionality. These included the ability to display animations on demand and the facility to accept and manage symbol input signals from an RFID reader when physical symbols were placed on the RFID reader (see later in this section).

These extensions were achieved by the incorporation of additional functionality using a flexible scripting language that CSLU toolkit supports for providing additional functionality called Tool Command Language and its associated Tool Kit (together known as TCL\TK 8.0). TCL/TK enabled CAPE Simulator to control output using the video Application Programming Interfaces (APIs). Modification to API software allows programmers to extend software functionality (and as a consequence computer hardware functionality) without the need to write complex software routines.

Designing and integrating the card symbol communication sub-system.

The implementation of an on-screen virtual tutor with an off-screen physical symbol card system required a sensing system and communication link to enable the software to detect and recognise a child's responses to tasks: the selection and placement of physical symbol cards. Radio Frequency Identification (RFID) technology was selected for this purpose. It offered an effective solution which enabled the look and feel of physical card symbols to be retained whilst providing an effective communication link / interface with the computer system (and the virtual tutor).

RFID technology can be implemented using either active or passive radio frequency identity tags. Using passive rather than active RFID technology for this investigation was beneficial in terms of safety. There were no on-board batteries and RFID tags were robust (surviving chewing by one participant - Chapter 6, Section 6.4).

With this approach, each tag can be detected and identified individually because of its characteristic reflection/absorption of radio frequency signals produced by a localised radio frequency generator. With each symbol being allocated a unique RFID identification code (ID), the RFID sensing system is able to detect the unique identifier of each symbol placed on the RFID reader. The communication between the RF device, the tags and the CAL system is managed and controlled by RFID 'middleware' that was programmed for the purpose of this study.

Figure 4.7: The RFID development kit components comprising RFID1 RFID tag reader/writer and RFID tags, (DLP Design, 2009)

RFID tags are produced in a variety of shapes and sizes. The RFID tag hardware adopted by this research was used in the CAPE Simulator and subsequent CAPE systems was purchased from a hardware manufacturer called DLP and is depicted in Figure 4.7. Label 1 in Figure 4.7 indicates tag shapes and sizes that were incorporated within the PECS symbols. The RF signal was generated and the reflection detected by the DLP-RFID1 reader / writer (Label 2). The DLP-RFID1

was relatively compact (of width 80 mm and height 55 mm) and supplied with an API that facilitated the control and interaction with the CAPE Simulator. The reader / writer was linked using a USB 2.0 cable (Label 3) to the computer hardware and hence the CAPE software, also providing the reader / writer with its power source.

The CAPE Simulator and later CAPE V1 and V2 were each designed as three software modules: a software interface that managed and controlled the user sessions; content modules that could be changed to cater for a range of curricular subjects; and middleware (known as the RFID-Bridge) that managed and controlled communication with the RFID reader / writer hardware. CAPE RFID requests to detect symbol placements could be sent using instructions, which were translated to RFID reader / writer commands compatible with the RFID-Bridge.

The researcher was able to trial different interface designs, employing a variety of programming languages, without having to re-engineer the RFID-Bridge communication code each time. This was achieved by creating a simple communication protocol to be used between the RFID-Bridge middleware and the implementation of CAPE (described here as 'abstraction'). Such an approach also allowed modifications and updates to be implemented without repercussions for linked modules.

Abstraction also allowed the RFID reader functionality to be simulated so that duplicate hardware systems were not required. For instance, software modifications to incorporate or modify system functionality could be carried out using an RFID Simulator application and installed later. This was particularly useful when the hardware itself was located in the collaborating school during the main study phase of the research.

The RFID-Bridge used two APIs to provide the required functionality. These were:

- Microsoft ActiveX networking API for use with Visual Basic 6 (VB6) applications. This allowed the required communication protocols to be defined between the RFID-Bridge and the CAPE application.

- DLP One Tag Design Library/API (for CAPE Simulator & CAPE V1) and DLP Multi Tag Design Library API (for CAPE V2) to allow communication between RFID-Bridge and the RFID reader/writer hardware.

With all systems active, the RFID-Bridge's main function was to 'listen' for a child's response to each task or request set by the virtual tutor. To achieve this the RFID-Bridge used the TCP port (number 1066) to monitor for any messages indicating a user response. Further technical details are provided in Appendix F, Table F1 and Appendix G.

Initially the RFID-Bridge was restricted by the DLP API to read a single RFID token during each read request. Whilst this was sufficient for the CAPE Simulator and subsequent pilot study trials, the main study trials involving CAPE V2, required multiple symbols to be detected and identified. For this purpose, an unrestricted version of DLP-RFID1 software (the DLP Multi Tag Design Library) was acquired.

CAPE Simulator user testing

User testing was undertaken during the early development of the CAPE Simulator by Matthew. Matthew's participation was strictly managed, using the same ethical rules that were adhered to in the pilot and main studies (Chapter 3, Section 3.5, Ethical considerations). Matthew's mother was asked and consented to Matthew

taking part and was present when he used the system. Matthew was restricted to using the system for a maximum of 10 minutes per session.

Matthew's attention to detail was instrumental in fixing many of the early code bugs associated with the CAPE Simulator. An example of test session findings is presented in Appendix I).

Appendix E, Table E1 serves to summarise the software and programming tools used to develop the required systems functionality in all the implementations of CAPE.

Figure 4.8 and Table 4.2 provide technical examples and data flows associated with RFID-Bridge symbol identification functionality that applied to all CAPE implementations. Colour coding has been used in Figure 4.8 and Table 4.2 to provide a clearer understanding of CAPE processes.

Figure 4.8: portion of the communication sequence diagram corresponding to the 'select symbol' process

Table 4.2: RFID-Bridge communication protocol

CAPE event	CAPE – RFID-Bridge communication	User input	RFID Reader and RFID-Bridge output
The virtual tutor requests the child to select a symbol	Character code 'r' requests the RFID-Bridge to check for symbols placed on the RFID reader and read their ID.	User places one or more RFID- enabled symbols on the RFID reader when prompted to do so by CAPE	When an RFID token is placed on the reader notification is sent to RFID-Bridge. The token(s)' ID are read and each ID is matched with a symbol description in a Microsoft Access database. The description is sent back to the CAPE application.
The virtual tutor requests that the child remove the current symbol from the RFID reader (tidy task)	Character code 't' instructs the RFID-Bridge to check if one or more symbols are on the reader.	The child removes the token from the RFID reader and places it in his or her PECS folder	If one or more tokens are detected then the RFID-Bridge will wait until the RFID tokens are removed. Once they are removed, the RFID-Bridge waits a further 500ms and then sends a "NONE" message to tell CAPE to indicate that the symbols have been removed and it is ready to proceed.

CAPE event	CAPE – RFID-Bridge communication	User input	RFID Reader and RFID-Bridge output
The child states that they wish to finish the session by selecting the 'No' symbol.	Character code 'c' is used to tell RFID-Bridge to close its TCP ports and shut down the RFID reader services. This function is only required when the CAPE system is closed at the end of a teaching session	CAPE requests confirmation that the session will close. In this instance, the 'Go back to main menu' button is selected and the current session is ended.	RFID-Bridge initiates the RFID close session command that instructs the RFID reader to close. Once RFID-Reader has received acknowledgement from the RFID reader to close it ends all active sessions with CAPE and closes.

127

4.4. CAPE V1

CAPE V1 was influenced by the findings from developing and testing CAPE Simulator and was later used in the pilot study. The pilot study was to be conducted in a classroom environment and involved a group of children with autism (whose guardians agreed to them being included). In the design of CAPE V1, several modifications were made and processes and routines specific to the pilot study were established. For example, alternative voice types were facilitated to probe the issue of voice-type preference of children with autism. The following description provides further details of the CAPE V1 implementation.

First, it was important that children involved in the pilot study should not be presented with unnecessarily unfamiliar objects or procedures. A number of commercial organisations provide graphic symbol images for use with symbol communication. This research adopted communication symbol images supplied by DynaVox Meyer Johnson (DynaVox Mayer-Johnson LLC, 2009) in CAPE V1 as they were already in use within the school where the pilot study was to be conducted.

In CAPE V1, the on-screen content locations were changed in favour of a linear left to right visual scanning of symbol choices used in PECS sessions, to make greater use of the space on screen. Adjustments to the positioning of windows on the computer screen are shown in Figure 4.9.
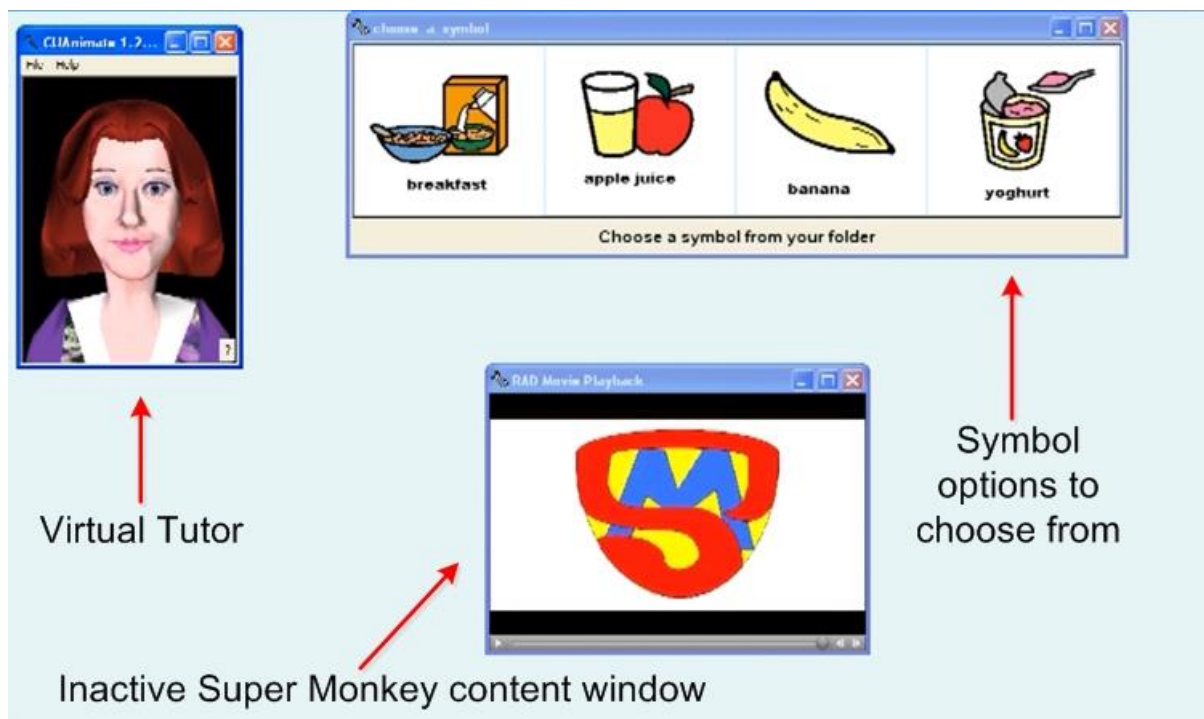
Figure 4.9: CAPE V1 screen user interface

In CAPE V1, task procedures were established corresponding to three different task types that the virtual tutor requested users to carry out. These tasks and the corresponding procedures are described next:

1. **The 'symbol selection' task:** The child was asked by the virtual tutor to choose a symbol from a set of four food and drink items for Super Monkey. These four symbols were suggested and provided by the host school (Breakfast, Apple Juice, Banana and Yoghurt). The physical symbols were stored in a PECS folder. In response to the request by the virtual tutor to select a symbol, the child was encouraged to place a food or drink symbol on the sentence board. This, in turn, was placed on the reader by the child each time a new symbol was chosen, and it remained on the reader until the child was asked to remove it (the CAPE onscreen content is shown in Figure 4.9). CAPE detected any response by means of a 'listen' request to

the RFID-Bridge (as described previously). If a food or drink symbol (for example, a banana) was detected CAPE played reward content such as that depicted in Figure 4.10 (Super Monkey eating the banana). Each task feedback took the form of a short animation of Super Monkey consuming the food or drink item selected. The selection was also backed up with verbal positive reinforcement by the virtual tutor. For example, in the case of the banana symbol being selected virtual tutor said "well done, Super Monkey hasn't had his banana today"

After each virtual tutor request CAPE paused for a second to give the child time to understand that an interaction had finished and to prepare themselves for the next interaction. At the end of symbol selection task the virtual tutor asked the child to put the symbol in the PECS folder. CAPE waited until the symbol was removed from the RFID reader before moving onto the next task.
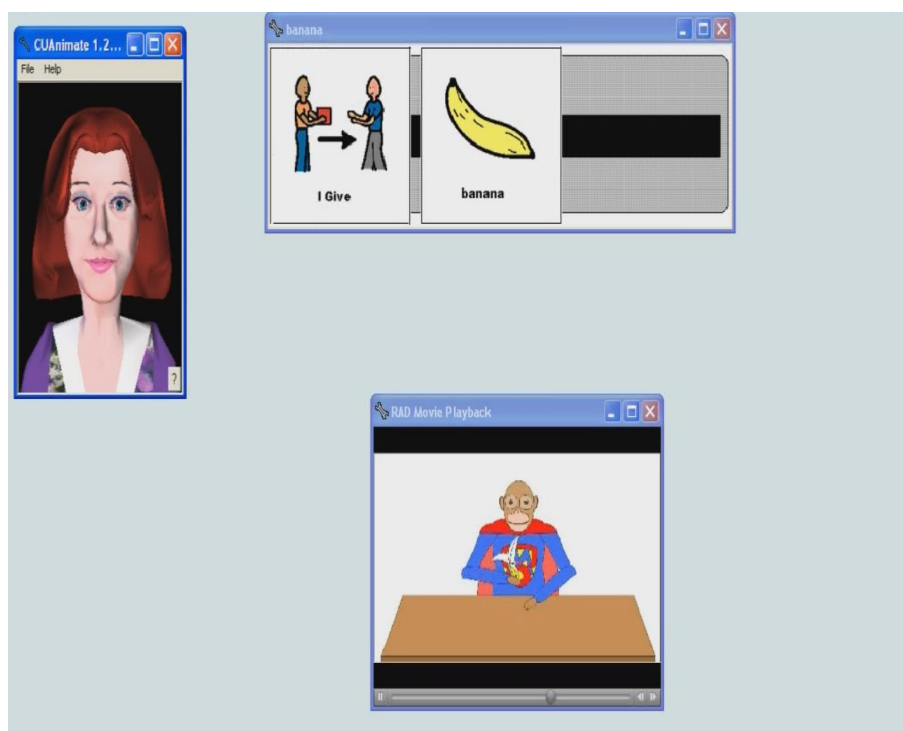
Figure 4.10: CAPE V1 'reward' animation shown after successful symbol selection

2. **The 'symbol tidy' task**: After each symbol interaction cycle, the virtual tutor asked the participant to remove the symbol. CAPE then instructed the RFID-Bridge to check if RFID tags were still detected on the reader. If one or more tags were detected, RFID-Bridge would continue to check for tags indefinitely or until no responses were detected. Once this happened, the RFID-Bridge replied to the CAPE tag detection request with the symbol-removed message ("NONE"). The symbol tidy differed with other tasks by not having onscreen content associated with it (Figure 4.11).
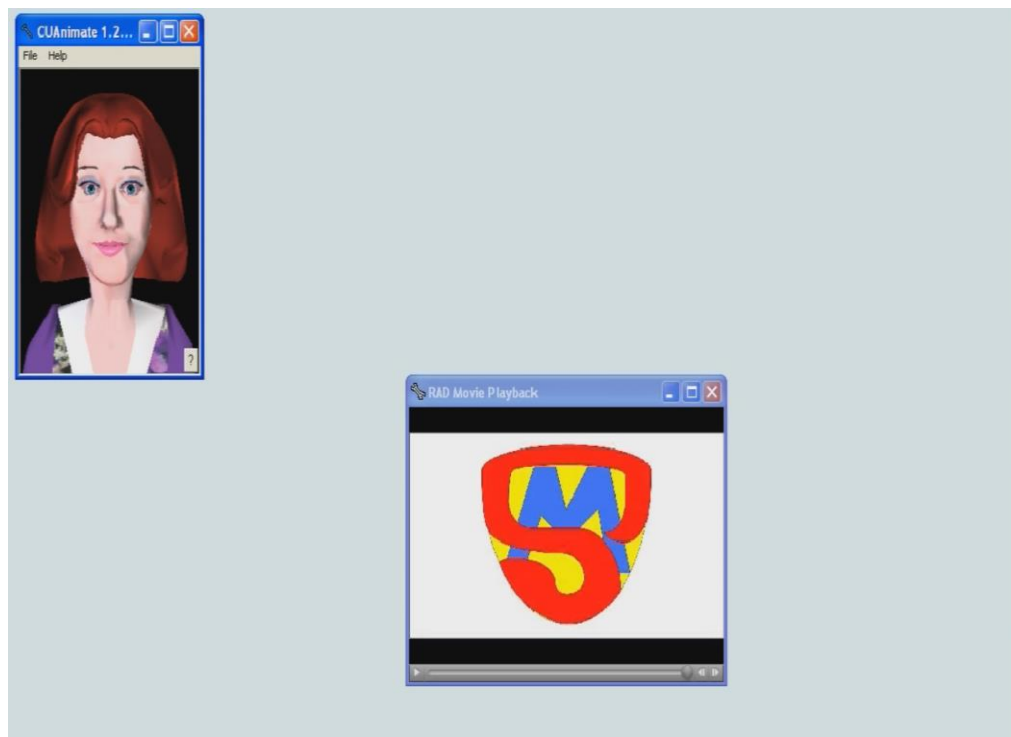
Figure 4.11: CAPE V1 screen following removal of symbol(s) from reader

3. **The *"choose another symbol"* task**: The virtual tutor then asked the child if they would like to choose another symbol, and offered them a choice of a Yes or No symbol to answer the question (see Figure 4.12). CAPE requested the RFID-Bridge to check if either the Yes or No symbol had been placed on the reader. If the RFID-Bridge reported that the Yes symbol

had been placed on the reader, CAPE would initiate the Symbol Tidy task (see point 2). However, if the RFID-Bridge reported that No had been placed on the reader, then, CAPE would initiate the Goodbye content after the Tidy task had completed. In the event that the user selected a symbol other than Yes or No, RFID-Bridge issued an error code that was sent to CAPE V1. In response to receiving the error code CAPE V1 informed the child that the selection they had made was wrong and asked the child to remove the symbol from the reader before asking them to select another symbol.
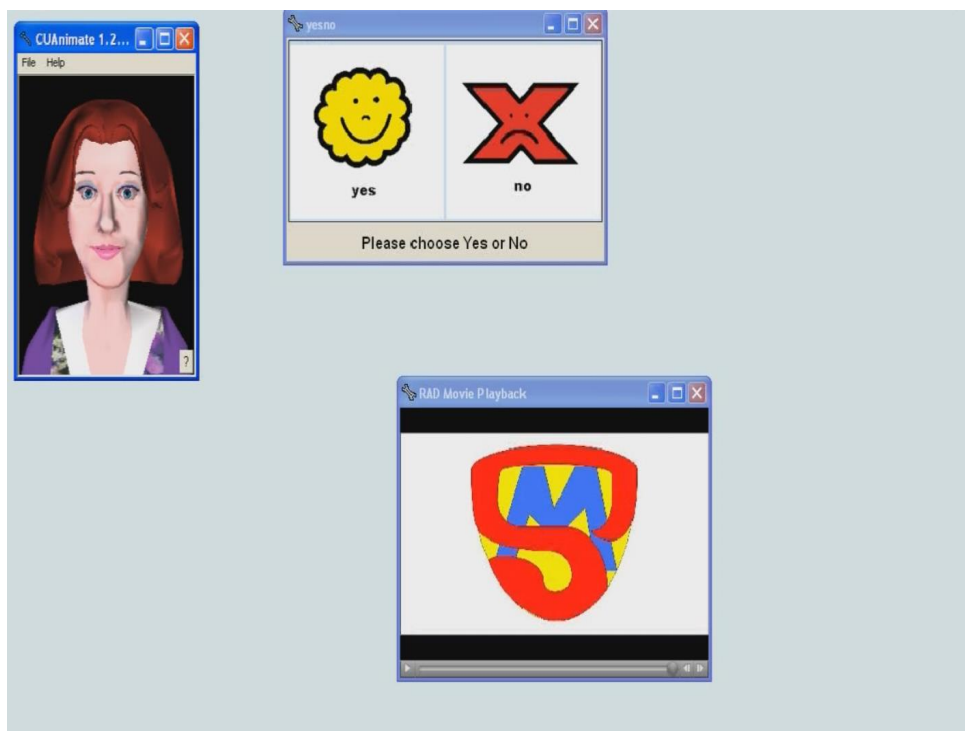
Figure 4.12: CAPE V1 screen – 'Do you want to choose another symbol?'

Natural and synthetic voice types

To test for sensitivity to voice type, two alternative virtual tutor voice types were supported in CAPE V1. A synthetic voice was based on a standard text to speech (TTS) voice creation feature of the CSLU RAD development environment. An alternative virtual tutor natural voice was also recorded in digital format. The voice originated from an adult woman and was typical (in dialect and inclination) of the area of the school's location. The natural voice used the same script as the synthetic voice. The provision of these voice types did not present any significant design or implementation challenges.

CAPE V1 provided a practical, usable system suited to the pilot study. It provided a means for establishing 'proof of concept', which could be taken forward into a more versatile version (CAPE V2) capable of supporting more specific curriculum-related learning tasks for the children.

4.5. CAPE V2

Experiences using CAPE V1 in the pilot study (described in Chapter 5) aided the further development of CAPE, to produce CAPE V2. This included the adoption of synthetic voice for virtual tutor verbal output and the use of Super Monkey reward content, which had proven to be very popular with the children in the pilot study. In addition, it was felt important that a CAPE teaching environment should be configurable to support individual children's learning needs.

Key additional design aims for CAPE V2 included:

- Development of a learning/communication environment that could support a variety of planned curriculum-based activities.

    - RFID-Bridge detection of three-symbol 'sentences' with a corresponding on-screen display of the physical sentence board.

    - Development of a system that could be configured to an individual user's needs.

- Improved system 'look and feel' to enhance the user experience and encourage sustained engagement in the learning tasks. The following resulted from CAPE V1 evaluation:

    - Improved accuracy of utterance of the adopted synthetic voice type.

    - Development of a finishing procedure that did not rely upon repeatedly asking the user if they wished to continue with the learning session.

The CSLU toolkit was very adaptable but unfortunately, did not provide virtual tutors with moving arms that would allow the virtual tutor to direct the child to different content on the screen and relied on the TCL/TK programming language, which was not universally supported by hardware manufacturers. To achieve the required design for CAPE V2 it was necessary to use additional programming tools beyond those adopted for the previous versions. A well-established software development tool with drivers and associated software libraries was needed. Visual Basic 6 (VB6) was supported by the RFID reader hardware vendor (DLP) and was selected because it provided a programming environment with which the researcher was familiar.

Early in the design phase of CAPE V2, curricular subjects were discussed with the host school to identify possible subjects that could be delivered using CAPE. It was decided that CAPE V2 would be used to help participants practice their counting skills. To understand how counting lessons using conventional PECS were conducted, the researcher attended two typical PECS lessons (one targeting counting and another combining colour and counting skills). Advice provided by teaching staff helped inform the CAPE V2 final design.

It was important to be able to tailor CAPE to specific learning needs of each child, for the curriculum area selected. CAPE V2 was therefore designed with customisable user profiles. This allowed each child to be provided with an individual symbol-learning plan for each session. It was considered that variations in the children's learning needs might require that alternative representations of number be used: Images of multiple items (picture symbols) for those children who had no familiarity with digit symbols at the start of the study, and digit symbols for those children who were able to progress to using them. In the final week of the main study some of the children who had struggled to use digit symbols were introduced to a set of picture symbols that depicted quantities of bananas (described here as the banana set) to see if they were able to distinguish between different quantities of the same object type rather than merely basing their selections on the object type itself (see Chapter 6, Section 6.2).

It was also important to provide an individual level of support for each child when they responded incorrectly to virtual tutor requests. For example, children with a lower understanding of a task may need to be shown a video demonstration of the task directly after an incorrect selection. Other children, with a higher level of understanding, would benefit from more chances to answer correctly, before the

virtual tutor provided support. To achieve these requirements CAPE V2 used a Microsoft Access database known as userData.mdb to record each child's needs and progress for the support teachers.

Access to the child's user profile was controlled through the CAPE configuration window (see Figure 4.14) which was designed to provide intuitive session configuration screens for use by the teachers. The configuration window allowed the teacher to choose how many new symbols would be taught. The teacher was also able to choose which previously taught symbols would also be included in the session, by selecting one of the lesson shortcut buttons (see Figure 4.13). Provision of a user guide and teacher training sessions enabled teaching staff to continue tailoring CAPE lessons to each child after completion of the research (see Chapter 6). The key features of the CAPE customisation process are depicted in Figure 4.13 and the CAPE user guide is shown in Appendix J).

The following description serves to demonstrate the steps required to configure an individualised CAPE V2 session.
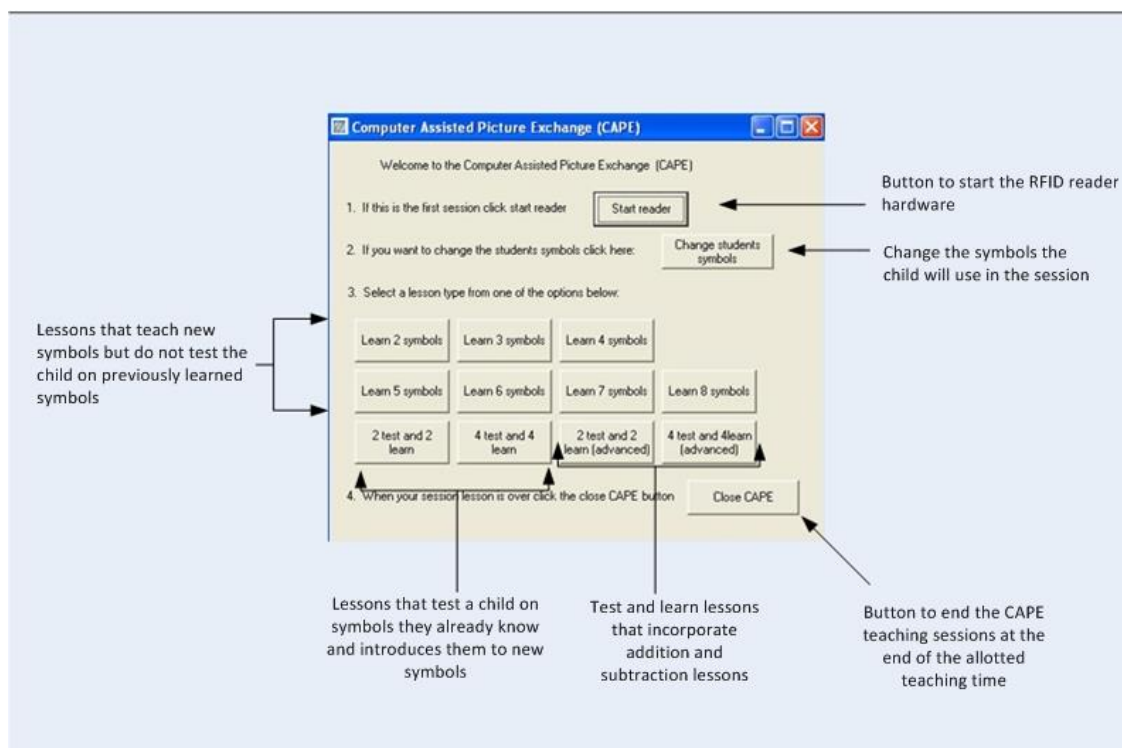
Figure 4.13: CAPE V2 lesson configuration window

The lesson configuration window was presented to the teacher at the beginning of each session. The teacher selected a series of configuration options to tailor CAPE V2 to the participant's needs (following the numbering provided in Figure 4.13):

1. At the beginning of a new teaching session, the teacher activated the RFID reader.

2. The teacher selected the symbols that would be used in the lesson and the order they would be presented to the child in the testing and new symbol phases of the lesson (see Figure 4.14, 'Symbols being tested' and 'New Symbols (with demonstration)'). For example, if the teacher wanted the child to be tested on their use of the '4 bananas' symbol they would refer to the CAPE V2 user guide (Table J1, Appendix J) and then enter the code 4b in the 'Symbols being tested' window (Figure 4.14). The symbols were presented in

order from left to right of the 'Symbols being tested' window (depending on the number of symbols to be tested in the lesson). However, if the teacher was happy for the child to use the symbols and the order from the previous session then no change was needed (see Figure 4.14). A list of the symbol codes are documented in the CAPE V2 user guide in Appendix J.
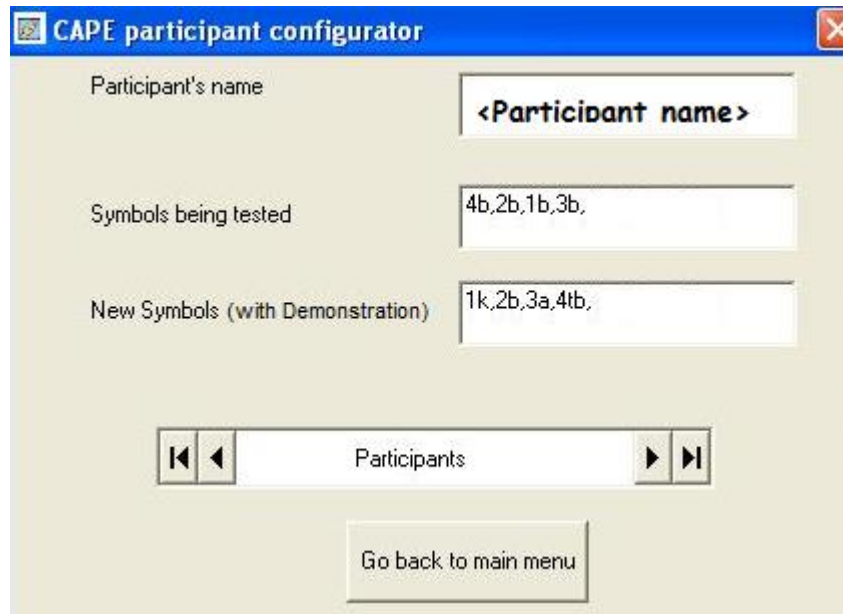
Figure 4.14: CAPE V2 user configuration window

3. The teacher could select from a variety of lesson strategies:

3.1. A 'learn only' option was provided in CAPE V2 to allow children with no prior experience of CAPE V2 to begin using the system (no testing of any previous learned symbols). This option helped participants to become familiar with CAPE and provided a greater level of learning support. The new symbols and counting tasks were introduced to the child by the virtual tutor. For example, the virtual tutor asked 'how many bricks can you see?' and then demonstrated how to complete the task.

3.2. Children mastering the basic symbol selection tasks were subsequently tested on symbols they had previously learned during a 'symbol test phase'. Once the child had successfully completed the test phase they progressed on to a 'learn new symbols' lesson for between two and four symbols, depending on the lesson plan chosen. The learn new symbols phase supported two lesson types; simple counting tasks that allowed the child to learn how to answer the questions using from one symbol to three symbol answers (for example: 'I See' - '5' - 'toy cars') and an advanced option that extended the basic counting tasks to more complex tasks such as addition and subtraction.

4. The teacher was given the option to close the CAPE V2 system, resulting in the RFID reader being shut down. All final sessions were closed in this way, replacing the process used in previous versions involving repetitive prompts to the user.

The session configuration window (shown in Figure 4.15) enabled the researcher or supporting teacher to select a participant's profile, which was accessed from the CAPE V2 database (userData.mdb), and which allowed the system to collect new user interaction data.
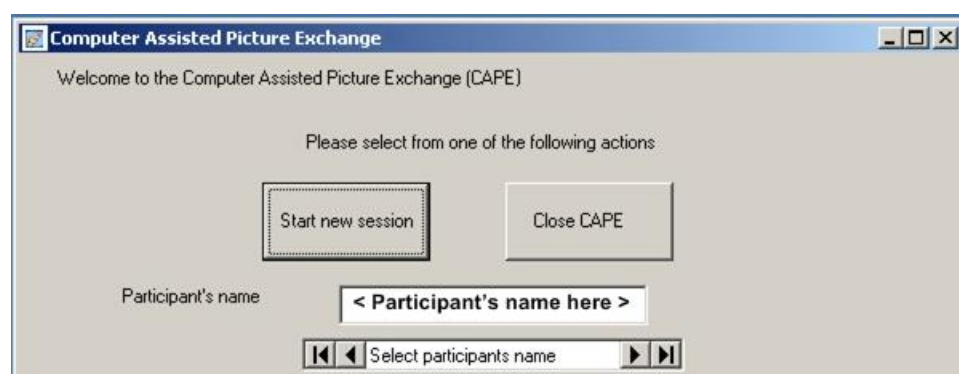
Figure 4.15: CAPE V2 session initiation screen

Additional improvements of the CAPE environment were included in the CAPE V2 design, as follows. The CAPE V1 virtual tutor consisted of the head and shoulders of a woman (see Figure 4.12). Unfortunately, this meant that the virtual tutor could not direct the child to look at different on-screen content using non-verbal requests (such as gestures). To direct the child visually to content it was therefore necessary to provide the CAPE V2 virtual tutor with the ability to point to on-screen content. This was achieved by creating a new virtual tutor with moving arms that could be used to direct attention to tasks and video content (shown in Figure 4.16). The virtual tutor was created using a Smith Micro Anime character called 'Mandy' and animated using Smith Micro Anime 6[©] Debut.

The CAPE V2 virtual tutor voice choice was informed by the results from the pilot study (see Chapter 5). The voice used was a computer generated synthetic voice, providing higher levels of utterance accuracy and prosody quality than had been available in the CSLU toolkit. The synthetic voice was created using Natural Reader 9 from NaturalSoft[©].

CAPE V2 incorporated improvements to animation content and visual representations of symbols. For example, in CAPE V1 Super Monkey had been hand drawn making creation of reward content very time consuming. To overcome this issue it was important to create a new Super Monkey based on a character template. The graphical representation of 'Super Monkey' was created by blending attributes of two Adobe Photo Shop cartoon characters (one of a gorilla and another of a human super hero) from a content company called Cartoon Creations (as shown in Figure 4.16). A front room set for Super Monkey was also added. By

adopting this approach, it was possible to improve the quality of Super Monkey
and shorten the creation time for reward content for CAPE V2.
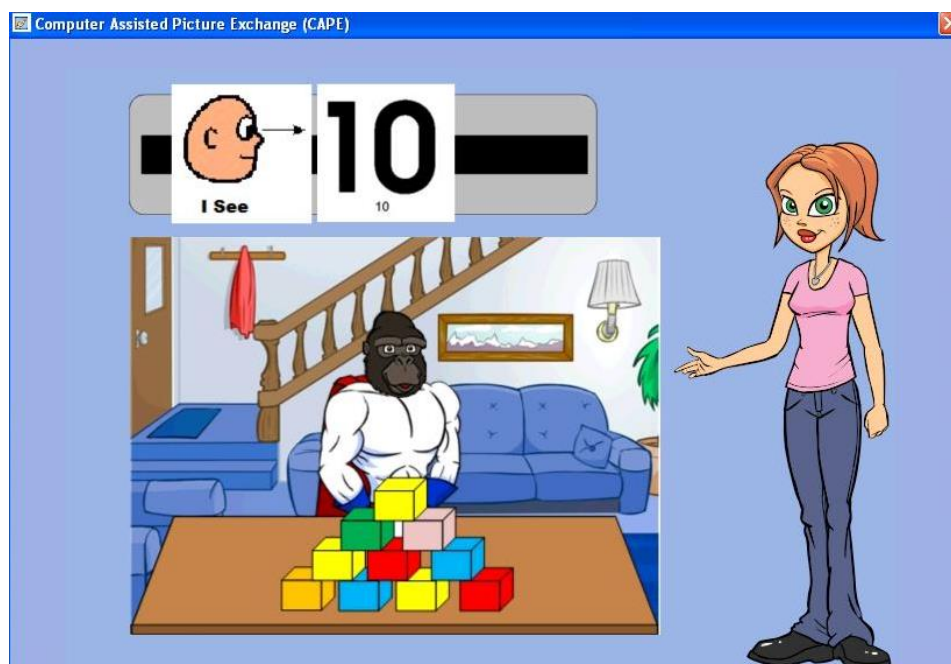
Figure 4.16: improved virtual tutor and Super Monkey visual content

Figure 4.17 shows an example of a three-symbol sentence being used to answer
the question "how many bricks does Super Monkey have?" The CAPE V2
interface was designed to detect the order of symbols placed on the sentence
board and to reorder the symbols where necessary in the onscreen representation
of the sentence strip to make a grammatically correct answer. For example, if the
child created a reply on the sentence board saying "10 bricks I see" CAPE
reordered the sentence to "I See 10 bricks" to help the child learn to construct
sentences correctly.
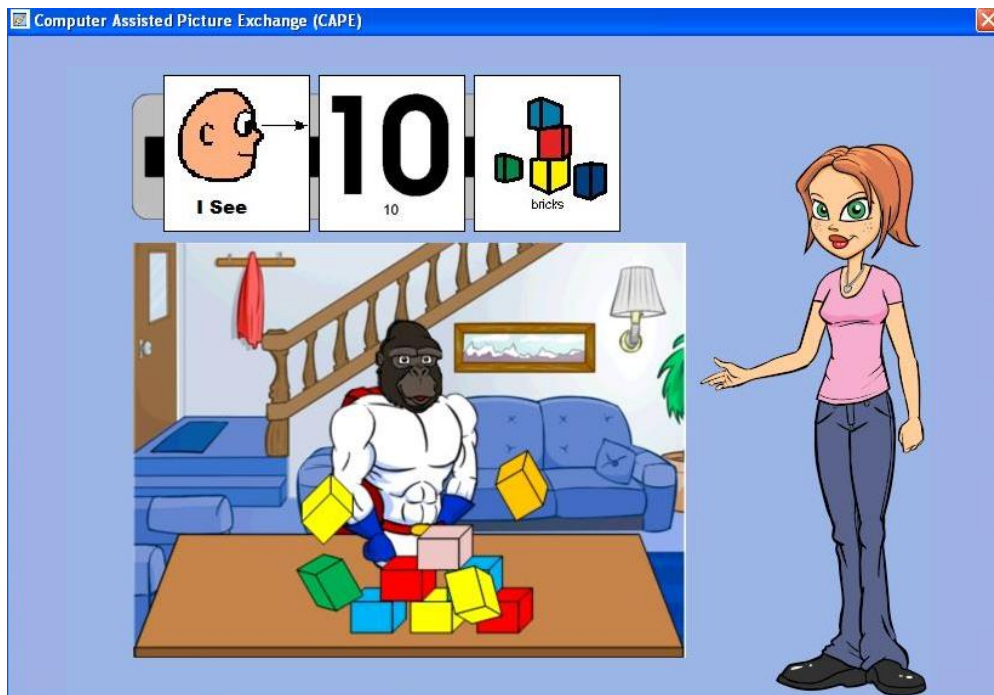
Figure 4.17: Super Monkey reward content

The controlled use of video clips provided a valuable way to encourage children to interact with the CAPE system. A number of different video media APIs were trialled. Initially Apple's QuickTime API proved to be difficult to control in a VB6 framework. This was because QuickTime operated as a separate application, making time sequencing with the CAPE interface difficult to manage. This issue was overcome by using a VB6 Timer object to control the order and timing of all program service requests.

Using a number of images representing generic objects like boxes or toy cars provided a quicker and more flexible way of developing Super Monkey animations for CAPE V2 content. During tasks that required the participant to focus explicitly on virtual tutor instructions the interface was configured to hide the Super Monkey content to limit visual overload (see Figure 4.18).
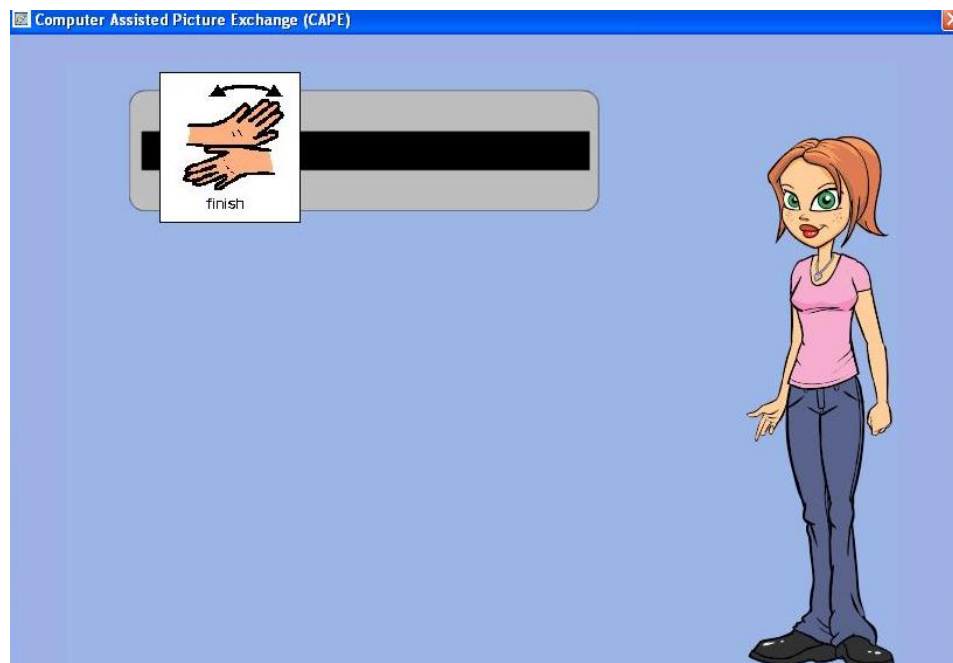
Figure 4.18: CAPE V2 – 'finish' symbol preceding session close

In CAPE V1 'Yes' and 'No' symbols provided a way for the child to indicate when they wanted to finish the session. However, experience from the pilot suggested that some of the children were unsure which symbols to use when they wanted to finish, often selecting both 'Yes' and 'No' to do so (discussed later in Chapter 5). The host school used a symbol that depicted the British Sign Language hand sign for 'finish' for this purpose. Therefore, CAPE V2 was designed to respond to a 'finish' or 'I see finish' symbol(s), should the participant place these on the sentence board and then on the RFID reader.

In CAPE V1 the request to finish (by selecting 'No') resulted in CAPE V1 shutting down. This had presented issues for children who had selected the wrong symbol and wished to continue with the session. To overcome this issue a closure verification window was added to CAPE V2 to allow the teacher to continue with the session if the child had selected the wrong symbol or to end the child's session without closing CAPE in preparation for the next child's session (see Figure 4.19).
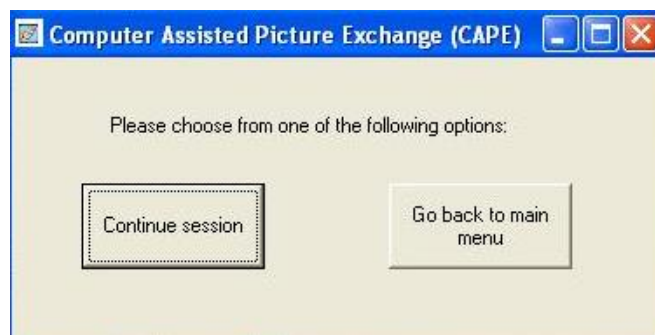
Figure 4.19 CAPE V2 – teacher controlled closure option.

4.6. Summary

The CAPE concept was developed using a combination of rapid application development and prototyping through three distinct phases of its use. In phase, one a test framework called the 'CAPE Simulator' was developed as a testing ground for visual and auditory content. This included testing a unique user input approach based upon RFID-enabled symbols, an RFID reader device and a 'middleware' (software) called 'RFID Bridge'. The RFID user input provided a novel way for children with autism to interact with a computer-based learning system using standard PECS-based symbols.

In the second phase, CAPE V1 was developed to offer children the ability to select food or drink items from a list of four possible choices. This version was to be used in a pilot study to provide 'proof of concept' and to investigate user preferences, such as virtual tutor voice type (Chapter 5, pilot study). Results from this study then informed the development of CAPE V2, the final version of CAPE, used in the main study (Chapter 6). The results from the pilot study are discussed in detail next in Chapter 5.

Chapter 5: Pilot study

5.1. Introduction

This chapter discusses the results from a pilot study, which was conducted as a proof of concept for the CAPE system, and which investigated the effectiveness of natural versus synthetic voice types for non-verbal children with autism. The chapter begins by discussing the rationale for the pilot study and its choice of methods. The chapter then discusses the results from the study and offers conclusions drawn from these results.

5.2. Reasons for the pilot study

The use of avatars to motivate engagement with aspects of the curriculum and promote social interaction has been shown to be effective for children with a wide range of social, communication and learning impairments, including autism. Massaro & Bosseler (2003) for instance, have demonstrated a preference by children with autism for virtual tutors, gauged through children's increased levels of engagement with particular activities (See Chapter 2, Section 2.3).

One aspect of user engagement with computer-based learning technology is the way the user interacts with the system; this can significantly influence how they respond.

RFID-enabled symbols have also been used to help to emulate PECS symbol exchange. However, the benefits of using RFID-enabled symbols, combined with the potential advantages of virtual tutor-led lessons (see Chapter 2, Section 2.7)

has not been investigated. The pilot study therefore addressed the following research question:

> Can a Computer Assisted Learning (CAL) system be designed and implemented to support PECS pedagogy for the purpose of improving symbol communication and social interaction in non-verbal children with autism?

Communication between a non-verbal child with autism and their communication partner can be supported through a combination of verbal and symbol-based communication. For example, the child's communication partner may use spoken communication and the child may respond using symbols. Avatar-led teaching studies have often used synthetic voice for virtual tutor verbal output. However, there is disagreement in the literature regarding which voice type most encourages learner engagement. For example, Williams et al. (2004) concluded that children with autism found the synthetic virtual tutor's voice 'too artificial' compared to human voice utterances; however, this aspect was not subsequently explored further (see Chapter 2 Section 2.6). The work by Williams et al. (2004) implied a possible conflict between preference for non-human appearance and the preference for human voice. However, a more recent study by Ramdoss (2013) found no significant difference between non-verbal children's preference for synthetic or human digitized voice. These findings suggest that children with autism differ from adults with typical cognitive development, who prefer consistent voice and appearance type (human face and natural recorded voice; or synthetic voice and computer-generated appearance) compared to mixing voice and appearance types (Gong and Nass, 2007). Therefore, it was important to

investigate how voice type influenced the children's ability to interact with a virtual tutor.

The pilot study considered this aspect of CAL/virtual tutor interaction i.e. the relative impact of using a synthetic or natural voice for a virtual tutor. Clearly, many variables might be manipulated in this respect: for example, pitch, tone, accent and speed. This pilot study used the same synthetic voice type, speed, accent, pitch and tone used in the Williams et al. (2004) study, and compared this to a recorded human (natural voice) alternative. Based on previous research (Williams et al. 2004; Gong and Nass, 2007) it was predicted that the virtual tutor's voice type would influence a child's engagement with the system; however, due to the disagreement in the research literature, a two-tailed hypothesis was used. The hypothesis predicted that there would be a significant difference in children's success in interacting with CAPE V1 between two voice types, but did not indicate the direction of this difference

To interact successfully with CAPE V1 the child was expected to respond appropriately to virtual tutor requests by selecting symbols or removing the symbols from the reader when requested. The null (or H_0) hypothesis was that there would be no significant difference in a child's success in interacting with CAPE V1 between the synthetic and natural voice conditions. The aim of the research was to evaluate the CAPE proof of concept to understand the effectiveness of the CAPE design and to investigate the possible influences that voice type may have on a non-verbal child's use of CAPE. Qualitative analysis was conducted to investigate the CAPE V1 proof of concept and quantitative analysis was used to investigate how voice type influenced the children's use of CAPE V1.

5.3. Research method

Non-verbal children with autism express themselves through their behaviour, rather than spoken language. Therefore, it was considered appropriate to adopt a mixed quantitative and qualitative research approach that would allow the researcher to observe and interpret a child's interactions with CAPE V1 as a method of judging the proof of concept. The research methods also needed to measure and compare children's responses to the two voice type conditions (natural vs. synthetic) to understand if one particular voice type was preferable for this group of children. Therefore, a quantitative method designed to compare each child's results from two voice type conditions, and capable of dealing with small population groups was necessary in this context.

Teacher views were important to this research. The support teachers had expert knowledge of: the children's level of enjoyment or anxiety as expressed through their exhibited behaviours; and the teaching practices used to teach symbol-based communication in this context. Teacher views were particularly important when considering the CAPE V1 proof of concept. To enrich the understanding of this group of children's interaction with CAPE V1, semi-structured interviews were conducted with the teachers during the study.

The remainder of this section describes the children who took part in the study and the ethical considerations and decisions that were made. The section goes on to discuss the research design, including the presentation and design of CAPE V1 and the qualitative and quantitative methods that were used to capture and analyse the data.

Participants

The children's ages have been represented here in years and the number of full months; this has been represented as <years>.<months>. Eight children participated in the study: seven boys aged 6.4, 7.1, 7.3, 8.1, 8.5, 6.9, 8.1 and a girl aged 6.5.

The participant selection criteria for the study required that each of the children's normal expressive language consisted of a maximum of one-word utterances and each child had a formal diagnosis of autism. All eight children were considered by their teachers to be pre-verbal. The expressive language for five of the children was similar to verbal output of typically developed infants, such as 'da, da' and 'ba, ba'. In some instances the children's' verbal output was representative of requests for desired objects such as 'ju' for 'juice' or 'bu' for 'breakfast'. Two children were reported by their teachers to repeat others' speech (echolalia) immediately after it had been said by someone talking to them, or to repeat full sentences the child had heard in the past. One of the children did not use any expressive language except when either distressed or happy, when he cried, growled or laughed.

Research design

CAPE V1 presented each child with a 'Super Monkey food and drink choice' activity in which a virtual tutor had either a natural or synthetic voice. The natural voice virtual tutor presented with a pre-recorded female human voice, originating from a person whose first language was English and who had a regional accent consistent with the children's locality. The synthetic voice virtual tutor presented with a female digitized voice similar to that used in the studies by Williams et al. (2004).

Each child experienced synthetic and natural voices in two separate sessions (described as Sessions 1 and 2). Each session lasted for a maximum ten-minute duration and Sessions 1 and 2 were conducted at the same time of day for each child, however sessions could be much shorter if the child opted to finish the session earlier. In addition, it was important to consider the time gap between sessions, and the issue of potential order effects, such as practice and fatigue. To address these issues, there was a gap of 48 hours between sessions, and a within–participants design was used. The order of the two conditions was counter-balanced; with the eight children assigned to two, equally sized groups (see Table 5.1). The use of a within-participants design effectively controlled for any significant variations between individuals; these would have been more problematic in other designs (see Chapter 3, Section 3.4).

Table 5.1: Counterbalanced study design

Group	Session 1	Session 2
1	Natural voice	Synthetic voice
2	Synthetic voice	Natural voice

As Table 5.1 illustrates, each group experienced both a natural voice and a synthetic voice condition. Group 1 experienced the natural voice first and the synthetic voice second; for Group 2 the order was reversed.

Children with autism are typically taught in small classes with predictable lesson structures and high teacher to pupil ratios. Class sizes in the school ranged from between five and seven students per class. Children with autism can become distressed if exposed to new experiences or people, so it was important to reduce possible anxiety triggers. To minimize the impact of possible increases in child anxiety caused by interacting with a person they did not know, and to disrupt as

few classes in the school as possible, four children from the same class who fitted

the selection criteria were recruited for Group 1 and four children from a second

class for Group 2. There was age difference between individuals or groups in the

research population. Also, comparison of the children's Individual Education Plan

(IEP) suggested variations existed in the level of cognitive and communication

abilities between individuals' in the study population. This was controlled for by

adopting a counterbalanced within-participant research design. The children were

assigned to the following groups:

Table 5.2: Child pseudonyms and group assignment

child pseudonym	Assigned group
Alan	Group 1
Brian	Group 1
Charles	Group 1
David	Group 1
Edward	Group 2
Fiona	Group 2
George	Group 2
Henry	Group 2

Teaching support for each group was provided by a member of the teaching staff

for the relevant class. During each session, the group's class teacher worked

exclusively with the children from their class. To control for differing teaching styles

an agreed teaching protocol was used consistently during each session (see

Appendix K).

CAPE V1 design

This study used a female avatar, with the same appearance as that used by Cole et al. (2003), to act as the virtual tutor. Although similar research has not included people with autism, it has been suggested that typically developed participants base their preference of voice gender on their stereotypes of particular roles (Forlizzi et al., 2007). For example, females may be associated with caring roles such as nursery nurse. The stereotype theory is further backed by statistical evidence of teacher gender ratios in early years and SEN education. Females are more likely to be encountered than males in teaching and classroom support roles in UK schools. For example in a General Teaching Council for England census it was estimated that only 3% of nursery staff, 12% of mainstream primary and 25% of Special Education teaching staff were male (GTCE, 2011). This ratio was much smaller in the host school, which had no male teachers working with children with autism between the ages of five and twelve years. These results suggested that the children would expect teachers, and presumably a virtual tutor, to be represented by a female in this context.

The CAPE V1 system was designed to run on a low specification netbook computer. The hardware peripherals (speakers, monitor and RFID reader) were attached by cables that were fixed securely to a class desktop to protect against health and safety risks to the children and teachers. The study was conducted in an unused activity room in the school. The CAPE V1 system layout is shown in figure 5.1.
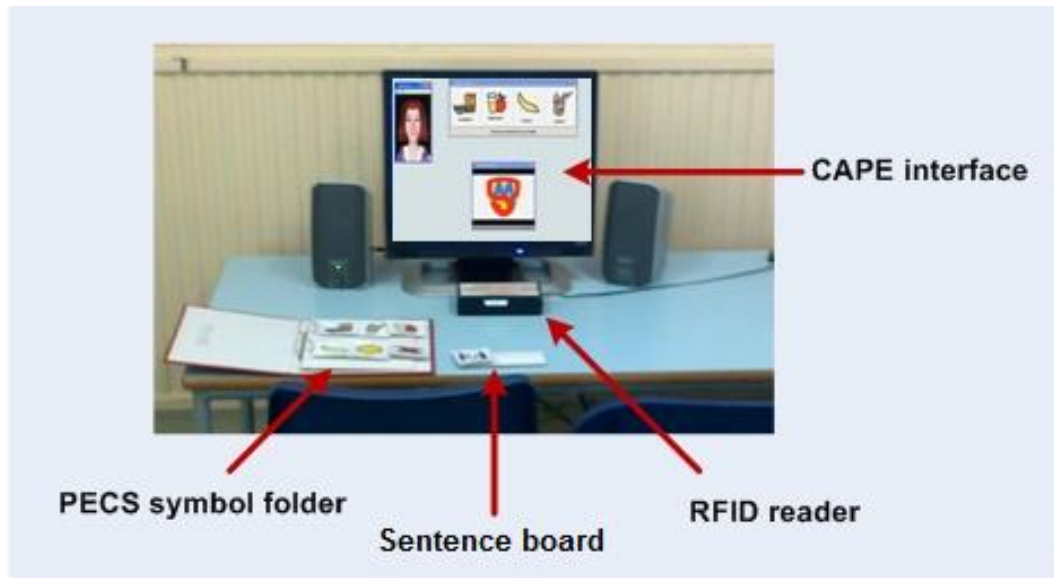
Figure 5.1: CAPE V1

The CAPE V1 system was designed to provide three types of task. Task 1, known as the 'food/drink selection task', offered the child four food/drink items (breakfast, apple juice, banana and yoghurt). The virtual tutor informed the child that Super Monkey had not had a drink or any food that day, and the child was asked to choose a food or drink item from the symbols provided (see Figure 5.2).

Figure 5.2: the food\drink selection task

The children were encouraged to choose a symbol from four symbol options and attach their chosen symbol to a board (known as the sentence board). The sentence board is a PECS method designed to help children to construct symbol phrases consisting of two or more symbols before completing a PECS symbol exchange. To complete the food/drink selection phase the child was asked by the virtual tutor to place the sentence board on the Radio Frequency Identification (RFID) reader to pass the symbol information from the child's chosen symbols to CAPE V1. This interaction simulated the act of handing a sentence board to a communication partner, a key part of the PECS symbol exchange. In this way, the child was able to reciprocate communication with the virtual tutor, (see Chapter 4 and Appendix K).

Due to a constraint with the software development kit (SDK) supplied with the RFID hardware, only one symbol could be read even if more symbols were placed on the reader (see Chapter 4, Section 4.4). To allow children to construct a simple two-symbol communication the 'I give' symbol was displayed on screen during all symbol selections and the physical 'I give' symbol was not configured to use an RFID token. Teachers supporting the study noted that the concept of selecting an item for another person was not taught to the children prior to the study. When the child placed the sentence board on the reader the virtual tutor verbally confirmed the name of the symbol the child had selected from the four possible choices shown in Figure 5.2, and a digital representation of the child's sentence board was displayed on the screen, adjacent to the virtual tutor (see Figure 5.3). Once the virtual tutor had verbally confirmed the child's choice, a short animation of Super Monkey consuming the item was played.
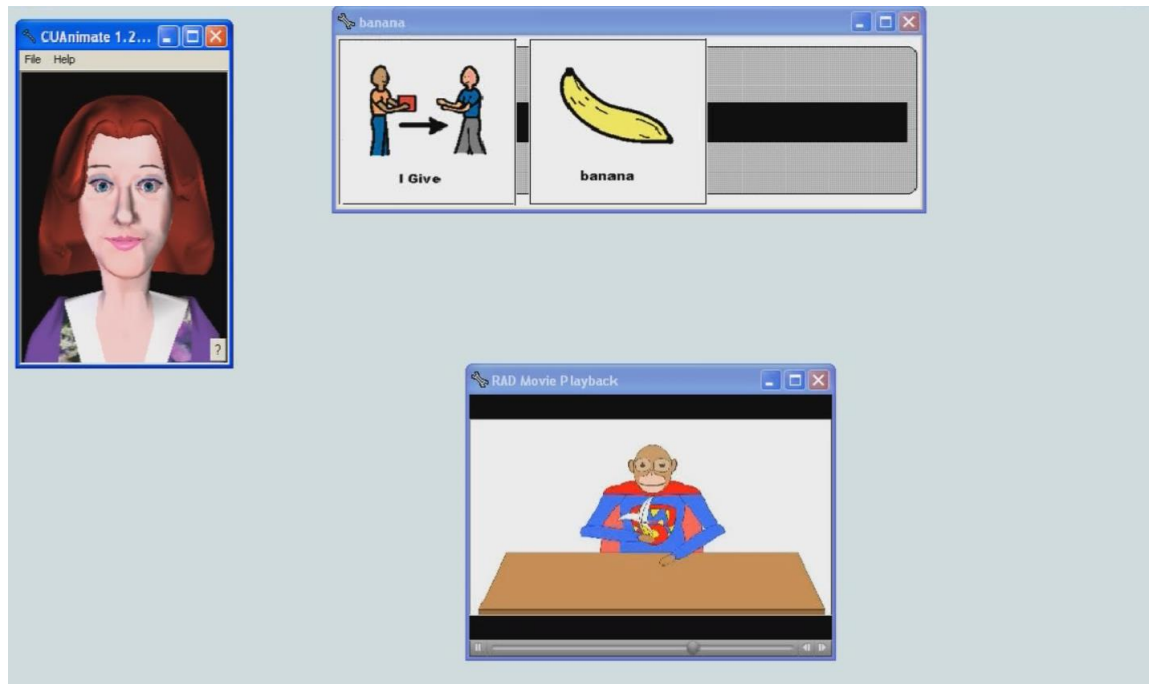
Figure 5.3: symbol selection confirmation

In Task 2, CAPE V1 displayed pictorial representations of the Yes and No symbols

(shown in Figure 5.4) and the virtual tutor verbally requested the child to decide if

he\she would like to continue selecting symbols (or would instead like to finish).
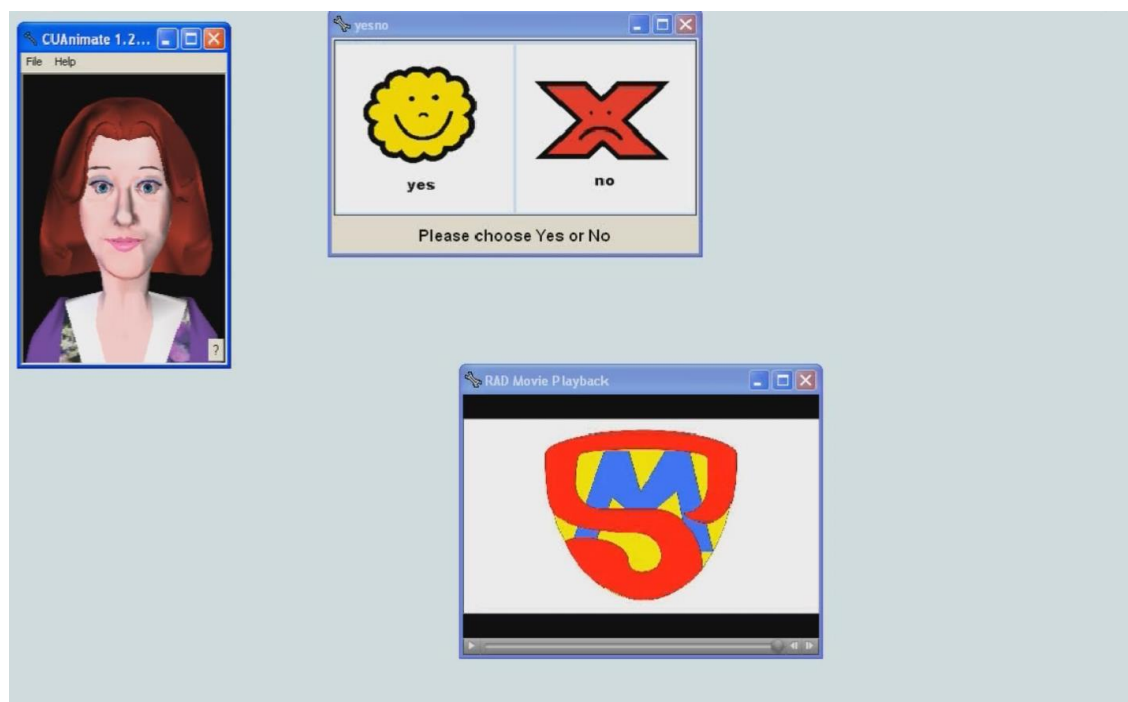
Figure 5.4: Task 2, The Yes\No task

The aim of Task 2 was to teach the 'Yes' and 'No' symbols to the children. Prior to the study, the children had not been taught to use the Yes' and 'No' symbols. This task provided an opportunity for the children to learn and practice decision-making, offering a second possible indicator of concept learning within the study.

Task 3 was a symbol tidy task. The symbol tidy task emulated the verbal request used at the end of a PECS symbol exchange to encourage children to put used symbols back into their PECS folder, before beginning a new symbol request. CAPE V1 symbol tidy was a verbal request from the virtual tutor. Task 3 was initiated at the end of each symbol interaction with CAPE V1. In Task 3, the virtual tutor asked the child to place the symbol back in their symbol folder.

CAPE V1 had not been used by any of the children prior to the study. To help the children understand how to use CAPE V1 it was necessary for the children to be shown how to communicate with the virtual tutor using symbols. This was achieved by inviting the child to watch their support teacher complete the first food/drink selection, tidy and Yes/No task of session 1 (described here as the modelling phase). The aim of the modelling phase was to demonstrate each task to the child before inviting them to interact with the virtual tutor.

Data gathering procedure

It was important to record user interactions with CAPE V1 as accurately as possible. To achieve this, a video camera was placed to the right of the computer screen to capture the CAPE screen output, each child's interactions with CAPE V1 and with the teacher, by recording the child's directions of gaze. Data, including researcher observations and recorded video, was captured for qualitative and quantitative analysis after each of the two sessions.

Qualitative data collection

Unstructured observations can be usefully employed to investigate the understanding and engagement of non-verbal children, who may have difficulty articulating their experiences when in learning environments (Cohen et al., 2008). It is important, with children who have little or no verbal ability, to observe and compare their behaviours to understand their motivations, likes and dislikes in this context. In the present study, the researcher acted as a non-participative observer and made field notes and recorded observations during each session whilst seated at the back of the classroom.

Making field notes to collect qualitative data provided an opportunity to record details of each child's interaction activity that may not have been evident using quantitative methods alone. For example, observation and recording of children's behaviour helped to develop an understanding of each child's level of engagement.

Semi-structured interviews were conducted with the teachers supporting the study, prior to commencing the pilot, and at the end of each research day. Interview questions were derived from researcher observations of sessions from that day. These interviews helped the researcher gain a clearer understanding of children's interaction with CAPE V1. During each interview, the session video footage was replayed to the teachers. Teachers' answers and comments were recorded by the researcher for later use.

Data analysis

All observational and interview data were coded shortly after the end of each day's session, using a thematic analysis approach (see Chapter 3 Section 3.4). The data were initially analysed using open coding. Related codes were then grouped into categories. This process included creating descriptions of the categories using memos. Categories were compared and became building blocks of themes that emerged from the study data. Initially data were coded based on the type of interaction (such as symbol selection or symbol tidy) with CAPE V1 and the surrounding environment, the type of communication and to whom the communication was being directed.

Quantitative data collection

To investigate whether there was a significant difference between the children's responses to natural and to synthetic voice, quantitative data were collected. To gain a detailed understanding, five aspects of the children's behaviour were measured for each of the two sessions. As children in the study are unable to express their feelings and needs using verbal communication, it was necessary to measure their observed behaviours. Aspects of behaviour were measured separately to gain a detailed understanding of the children's ability to use CAPE V1 and their interest in it. The following data were collected:

1. The number of symbols selected that were correct for the task that the child was asked to complete.
2. The total time the child spent looking at the computer screen and the symbols.
3. The total time the child spent looking at the support teacher.

4. The mean time taken by the child to respond to requests from the virtual tutor that included onscreen images to prompt the child to respond to the request.

5. The mean time taken by the child to respond to requests from the virtual tutor that did not include a visual prompt.

Measure 1 (number of symbols selected appropriately) gave an indicator of whether the child was able to us CAPE V1 as intended. Measure 2 (total length of time a child was observed to interact with CAPE V1) was used as an indicator of a child's interest in CAPE V1.

The literature suggested that computer use could help to instigate social interaction by children with autism with support teachers, to share their experience. Measure 3 (time spent looking at the support teacher) was therefore designed to obtain some measure of social interaction in this context.

Measures 4 and 5 (response times to requests with and without visual prompts) were further indicators of whether children were able to use CAPE V1 without difficulties. It was expected that virtual tutor requests with visual prompts would be easier for the children to respond to.

The analysis of small and idiosyncratic participant populations using quantitative parametric testing is likely to provide misleading results (Leech and Onwuegbuzie 2002). For small samples that do not conform to a normal distribution, a non-parametric approach is needed (Siegel and Castellan, 1988), which can have more power in this situation than parametric tests (Leech & Onwuegbuzie, 2002). A within-participant design allows non-parametric analysis to be undertaken on a sample of this size, allowing levels of significance to be reported (Leech and Onwuegbuzie, 2002; Siegel and Castellan,1988). The data was therefore analysed

using The Wilcoxon signed-ranks test (see Section 3.2, Chapter 3 for a description of the Wilcoxon signed ranks test).

5.4. Results

This section discusses results from a mixed methods approach consisting of quantitative and qualitative analysis of children's interaction with CAPE V1. This section will discuss qualitative results next.

Qualitative results

This section discusses the results from thematic analysis of researcher notes, video recordings of child interactions with CAPE V1 and semi-structured interviews with teachers supporting the study. Each of the themes are reported with supporting quotes from the data and is annotated as either (session transcription) for data derived from transcriptions of session video recordings or (researcher notes) when data was written by the researcher during the session. Teacher interviews were recorded using a Dictaphone and later transcribed before being analysed using thematic analysis (see Appendix P for an example of the interview schedule). The themes presented represent the following aspects of the study:

- Introducing children to CAPE V1

- Prompting and engaging children with CAPE V1 activities

- Finishing the sessions

- Examples of children's communication

- Teacher interviews

Introducing children to CAPE V1

To motivate the children to use CAPE V1 it was important that the system drew their attention to the computer screen and that appropriate support was given to help them understand how to communicate with the virtual tutor. This was achieved by providing a virtual tutor greeting at the beginning of each session and having the task modelled for them by the human teacher. Analysis of the observations from the beginning of each session for each group resulted in the following themes:

Table 5.3: Themes resulting from children's introduction to CAPE V1

Theme number	Theme description
5.1	Virtual tutor gains children's attention
5.2	Children enjoyed watching Super Monkey content
5.3	Task modelling helped children learn to communicate with the virtual tutor

Theme 5.1 - virtual tutor gains children's attention

The initial verbal greeting by the virtual tutor by saying "hello" and waving to the child helped to draw children's attention to the system.

Alan – Session 1(session transcript) *"[Alan] was not watching the screen when virtual tutor stated "hello" and this verbal prompt created instant interest from him*"

Fiona – Session1 (researcher notes) "W*hen virtual tutor says "hello". During initial intro [Fiona] looks at teacher and rubs her right eye*"

George – Session 1(session transcript) *"When virtual tutor stated "hello" [George]'s attention was drawn to the CAPE V1. When virtual tutor finished talking [George] began to play with the symbols"*

Theme 5.2 – Children enjoyed watching Super Monkey content

To enhance the children's interest in CAPE V1 an animated greeting by 'Super Monkey' was used (see Chapter 4 Section 4.5). This was particularly engaging for six of the eight children.

Alan – Session 1 (session transcript) *"Participant showed good levels of engagement with interest mainly focused on Super Monkey. This interest remained on Super Monkey even when virtual tutor was introducing the symbol select task"*

Alan – Session 2 (session transcript) *"When the Super Monkey video completed [Alan] looked at the teacher and smiled"*

Charles – Session 2 (session transcript) *"When virtual tutor said "hello" [Charles] waved and attempted to say hello by verbalising "ha, ha". He then pointed to Super Monkey and said "mokee" whilst showing signs of excitement."*

David – Session 1 (session transcript), *"When the Super Monkey video for yoghourt was played [David] began to ring his hands. Teacher 1 had observed that this behaviour was only carried out by [David] when he was interested in a particular activity. Super Monkey seemed to be [David]'s primary interest in CAPE"*

Edward – Session1 (researcher notes) "*When Super Monkey began to demonstrate eating breakfast [Edward] smiled and pointed to Super Monkey*"

Theme 5.3 – Task modelling helped children learn to communicate with the virtual tutor

In Session one, the supporting teacher demonstrated initial symbol selection and symbol tidy tasks to each child. The same symbol ('banana') was selected during the modelling phase of each session. The support teacher verbally stated the symbol selection choices she was making by saying, "I give banana". All of the children showed interest in the modelling process. At the beginning of Session 2 only Alan and Henry, both of whom were reported by their teachers to find new concepts difficult to understand, which resulted in hand-over-hand support being used by the teacher to support the children's interactions with CAPE.

Alan –Session 1 (session transcript) "*Supporting teacher [teacher 1] then began an agreed task modelling activity to demonstrate to the participant what they would need to do by selecting 'banana symbol' and verbalising choice. [Alan] was fully engaged with this process*"

Brian – Session 1 (researcher notes) "*Teacher responded to request to choose a symbol by modelling the selection of 'banana'. [Brian] observed activity with interest*"

George – Session 1 (session transcript) "*During the teacher modelling of the symbol selection task ('banana') [George] showed interest in the symbol interaction process*"

Henry – Session 1 (researcher notes) *"[Henry] showed interest in the task modelling of the symbol selection task."*

Prompting and engaging children with CAPE V1 activities

Children's interaction with CAPE V1 was analysed and two themes emerged (see Table 5.4).

Table 5.4: Themes derived from analysis of children's interactions with CAPE V1

Theme number	Theme description
5.4	Teacher support was required to help children complete symbol tidy tasks
5.5	Children switching attention between virtual tutor and Super Monkey

Theme 5.4 – Teacher support was required to help children complete symbol tidy tasks

In the early stages of Session 1 the children found the 'symbol tidy' task harder to understand than the other tasks. Their difficulty with this task might have been due to a lack of visual cues shown, compared to the food/drink and Yes/No tasks, where symbol options were shown on the screen. However, four children started to remove the symbol without the need for teacher prompting by the later stages of Session 1, with this trend continuing in Session 2.

Alan - Session 1(session transcript) *"[Alan] did not react to the virtual tutor request so the support teacher used a non-verbal prompt which resulted in a correct response by [Alan] to remove symbol from reader (symbol tidy)"*.

Charles - Session 1 (session transcript) "*Removal of the symbol did require a prompt from the teacher. However, once prompted, [Charles] completed the tidy task without further help from the support teacher*".

Edward - Session 1 (session transcript) "*[Edward] did not, however, respond to the request. It should be noted that the symbol tidy task has no visual prompts, unlike all other requests. Also, when the teacher prompted [Edward] to remove the symbol he attempted to select another symbol*".

George - Session 2 (session transcript) "*When virtual tutor asked [George] to complete a symbol tidy he seemed not to hear the request [...] and required further prompts from the support teacher [Teacher 2]* ".

Theme 5.5 – Children switching attention between virtual tutor and Super Monkey

The ability for a child to switch their attention between different points of interest was important in this study. Six of the children were able to switch attention between the virtual tutor and Super Monkey, depending on which was active at the time. However, some children found this difficult.

Brian - Session 1(session transcript) "the support te*acher responded to the request to choose a symbol by modelling the selection of 'banana'. [Brian] observed the activity with interest. [Brian] watched Super Monkey intently but he did not look at the virtual tutor when she was active*".

Charles - Session 1(session transcript) "*Feedback from the virtual tutor seemed to make [Charles] happy. He smiled and focused on virtual tutor. When Super Monkey started he switched his focus to Super Monkey and when the clip finished and virtual tutor spoke he smiled again*".

Edward - Session 1(session transcript) *"[Edward] is mainly interested in Super Monkey during the start-up sequence; this is not surprising as Super Monkey was the most visually active at this time. However, when virtual tutor started to speak [Edward] focused on the virtual tutor*".

Henry - Session 1(session transcript) "*When the teacher prompted [Henry] to look at the computer screen he seemed surprised and became very interested in the virtual tutor, especially when she spoke. When Super Monkey waved [Henry] used the teacher's hand mechanically to wave to the screen*".

Problems finishing the sessions

The children had problems finishing a session. This was probably because task modelling did not include a demonstration of how to finish a session. These factors had an impact on the way that the children behaved in the last few minutes of using CAPE V1. Analysis of children's behaviours at the end of their sessions resulted in the following two themes:

Table 5.5: Themes resulting from behaviours exhibited by children when finishing a session

Theme number	Theme description
5.6	Children became distracted near to the end of their session
5.7	Children had difficulty understanding how to finish a session

Theme 5.6 – Children became distracted near to the end of their session

In the later parts of both Sessions 1 and 2, each child became more distracted and spent less time looking at symbols and the CAPE monitor screen.

Charles - Session 1 (session transcript), "*When the virtual tutor asked [Charles] to choose another symbol [Charles] became distracted. But became focused again on the task when prompted to complete it by his teacher*"

Fiona - Session 1(session transcript) "*When prompted [Fiona] said "yogt" and selected breakfast. [Fiona] showed interest in Super Monkey, virtual tutor and in the folder but she became distracted shortly after*"

Henry - Session 1(session transcript) *"[Henry] was beginning to become distracted and showed no interest in task. The teacher reduced the number of symbol choices available to [Henry] from four to two symbols and prompted [Henry] to make a choice. After much thought [Henry] chose 'yoghourt' and turned away from screen*"

Theme 5.7 – Children had difficulty understanding how to finish a session

Children had difficulty selecting the correct symbol during the final Yes\No selection of Session 1. Children were asked by the virtual tutor "do you want to choose another food or drink for Super Monkey" and were asked to select either Yes or No. Five of the eight children selected the 'Yes' and 'No' symbols and placed both on the RFID reader as a way to finish a session (Brian, Alan, David, George and Fiona). This theme suggests that the children did not understand how to answer the question, particularly when they wanted to finish the task.

Alan - session1 (session transcript) "*He selected the Yes and No symbols together. During the Yes/No tasks, he had continually selected Yes and he seemed unsure if he needed to select Yes and No when he wanted to finish. No had not been selected during tasks so No was not been learned*

by [Alan]. However, [Alan] also verbalised "no, no, no" so did want to finish".

Charles - session 2 (session transcript) "*when [Charles] was prompted to select either Yes or No he chose both (Yes\No confusion) matching these to the digital representations on the screen. He said "No" and waved goodbye".*

Fiona - session1 (researcher notes) "*When prompted to choose Yes or No, [Fiona] said yes but pointed to No. The teacher [Teacher 2] prompted for her to choose and she selected No*".

Examples of children's communication

Over two brief sessions the children began to attempt to communicate, verbally and non-verbally, with the virtual tutor, Super Monkey and the support teacher. The following communication-related themes emerged from the data:

Table 5.6: Themes derived from verbal and non-verbal communication

Theme number	Theme description
5.8	Children used verbal communication during the study
5.9	Children wanted reassurance from their teacher

Theme 5.8 – Children used verbal communication during the study

Seven of the children responded to verbal requests from the virtual tutor and the support teacher. Utterances took the form of echolalia, attempts to verbalise the names of food and drink items and attempts to talk to Super Monkey.

Brian – Session 1 (researcher notes) "*When VT states Goodbye and SM waves goodbye [Brian] waves and verbalises "b, b""*

Charles – Session 1(session transcript) *"At the beginning of the session [Charles] was very interested in the symbol folder. [Charles] began to select a symbol before CAPE V1 had started. The teacher asked [Charles] to wait which resulted in [Charles] saying "wait"*

David - Session 1(session transcript) "*He tries to hand the board to the teacher saying "h, ya". However, he places the board on the reader when prompted by the teacher. Once the board is on the reader he verbalises "gi, giv" (I give)"*

Fiona – Session 1 (researcher notes), "*When SM waved goodbye Fiona rubbed SM and looked at teacher. When teacher said "good bye" to [Fiona] she stated "good bye" and waved*"

Theme 5.9 – Children wanted reassurance from their teacher

In Session 1, five children looked at the teacher directly after selecting a symbol to receive reassurance or approval. During early instances of social interaction, children attempted to hand the sentence board to the teacher, as they would in the PECS communication exchange.

Alan - Session 1(session transcript) *"After the Super Monkey animation had finished and virtual tutor requested that [Alan] to start the symbol removal process [Alan] looked to the teacher for reassurance".*

David - Session 1 (researcher notes), *"When [David] was instructed to remove the symbol he verbalised "tu" and then looked at the teacher for*

guidance. The teacher reacted by saying "yes" and guiding [David] through the symbol removal process".

Fiona - Session 1 (session transcript) "*When the Super Monkey banana video finished [Fiona] looked at the teacher (possibly to share the experience with the teacher) and then rubbed her eye*"

George - Session 2 (researcher notes) "*When the Yes and No task started [George] looked at the teacher and then pointed to 'apple juice' but selected Yes and put it on the reader*"

Henry - Session 1 (researcher notes), "*When requested to remove the symbol by virtual tutor [Henry] took the teachers hand and placed it on the breakfast symbol*"

Teacher interviews

Five semi structured interviews were conducted – one with each of the two teachers supporting the study. One interview was just prior to the study commencement and one at the end of each research day, with the teacher who had been working with the children on that day. The interviews were captured on a Dictaphone and supplemented by notes written during the interview.

The teacher interviews provided a useful way of gaining a more detailed understanding of the children's behaviour during the pilot study. Interview transcripts were analysed using a thematic analysis technique to identify emergent themes. Analysis resulted in the themes shown in Table 5.7.

Table 5.7: Themes resulting from thematic analysis of teacher interviews

Theme number	Theme description
5.10	Children's experience and motivation influenced the symbol choices they made
5.11	Some children were confused about finishing their session using the Yes and No symbols
5.12	Children awareness of the virtual tutor's verbal instruction developed over the study
5.13	Repeated exposure to tasks helped to support learning
5.14	On-screen content was motivating
5.15	CAPE could be a very useful teaching tool

Theme 5.10 - Children's experience and motivation influenced the symbol choices they made

Both teachers expressed the view that the children initially selected symbols in order of the symbols' presentation on screen, from left to right. The teachers believed that the children chose symbols in the same order as the visual prompt that the teachers used to request a child to select a symbol in Session 1 (for example, pointing to each symbol in turn and verbally stating the item's name). It was felt that the children's behaviour changed in the second exposure to CAPE V1. Teachers observed that the children selected symbols that represented food or drink items that were based on their previous experience and were motivating for them. For example, a child who liked to drink apple juice may be more likely to select the CAPE V1 apple juice symbol than a less motivating food type like banana.

After taking part in Session 1, the teachers made the following observations:

Teacher 1: "I think he was going through the visual clue at the top…the choices, so he wanted Breakfast, Apple Juice and I thought he was going to do Banana, but he missed out Banana and went back to breakfast, but he is quite rigid in his thought..."

Teacher 2: " I think he had used all the pictures so he thought he was finished...he had done his job."

After taking part in Session 2, Teacher 1 commented:

"Last time he seemed to choose the first symbol he saw...this time, he spends time to choose the one he wants. He is making choices this time."

Theme 5.11 - Some children were confused about finishing their session using the Yes and No symbols

Children were asked if they would like to choose another food or drink item for Super Monkey after the completion of each symbol selection task. The Children could select the symbol for 'Yes' (I would like to choose another food or drink item) or 'No' (I would like to finish the session). However, children selected the Yes and No symbols together to end Session 1 (five of the eight children did this). Teacher 1 felt that this was because the children concerned had not used the Yes or No symbols prior to the study and were still confused about the meaning of No and its relationship to 'finish' in this context. The teachers made the following observations:

Teacher 1: " Yes, he wanted to finish, I think he put Yes on because that was what he had already done."

172

Teacher 2: "he did understand what was being asked of him. At the end he chose the symbol No and said 'No'. He then picked up both symbols [yes and no] then he put Yes down, so it was a definite choice not any symbol will do, yeh, very interesting."

Teacher 1: "I didn't think the boys would understand Yes and No. We don't normally teach them Yes and No until they have a better grasp of PECS but I think it may be a good idea to keep using the symbols...it would be very useful on trips."

Teacher 2: "I really thought they would find it difficult to get Yes and No because they are very rigid so concepts are difficult for them to understand".

Theme 5.12 – Children awareness of the virtual tutor's verbal instruction developed over the study

Teachers felt that the children in the study developed an understanding of virtual tutor verbal instructions in the later stages of Session 1 and in Session 2. For example, Teacher 1 felt that Brian became aware of verbal instruction in his final interactions with the virtual tutor in Session 1. In Session 2 Teacher 1 felt that Brian became more independent and was more aware of the virtual tutor's requests, and seemed to develop an understanding of what she was asking him to do.

Teacher 1: "I felt that Alan didn't understand the language used, he didn't respond because he understands the routine. I think it confused him and that is why he said no. Compared to Alan who was listening to what she

173

[virtual tutor] was saying and he responded straight away...he tried to say 'I give breakfast', didn't he, when he handed the strip up"

Theme 5.13 – Repeated exposure to tasks helped to support learning

Both teachers expressed the view that that CAPE V1 helped children to learn due to the repetitive nature of the tasks. The teachers expressed the view that the ability for a child to repeat tasks allowed them to learn at their own pace.

Teacher 1: "the advantage of your software [CAPE V1] is the way that it lets the children repeat tasks for as long as they like. My boys really benefit from rote learning so they really enjoy using it"

Teacher 2: "the software isn't really a teaching tool at the moment but it has some real pluses…the repeated tasks really helps the children to learn how to do the tasks at their own pace."

Theme 5.14 – on-screen content was motivating

The Super Monkey character was considered very motivating by both teachers in the study. Both teachers also suggested ways of improving the on-screen content to engage with children further.

Teacher 2: "well, I think the software motivates children in different ways [Henry] really likes the lady [virtual tutor] but [Edward, Fiona and George] like the monkey better."

Teacher 1: "if it had music, that was a thing I did think, maybe it would have kept them more engaged."

Teacher 2: "I wonder if the image was a little more motivating for him [Brian], I know Super Monkey was motivating but if it was say...I don't know what is motivating for him, say like Buzz Light-year"

Theme 5.15 - CAPE could be a very useful teaching tool

Both teachers expressed the view that CAPE V1 could be a useful way of teaching curricular subjects like reading, maths, and food and colour symbols to this group of children.

Teacher 1: "I think that the software has been very useful. I mean, it doesn't follow a proper teaching format but if it did, I think it would be really useful for teaching basic PECS, like food items, and colours...I know it can't do it now but if it could help teach maths then that would be great. Numeracy is a really difficult concept for these boys to learn and I think that something like this could really help."

Teacher 2: "the idea you have is quite good but young children may need to understand computers to use it. Saying that, the software the children have used this week with my group has helped them to learn new phrases like 'I give'. With a few changes we could use it to teach colours to the children quite easily".

Quantitative results

Findings from qualitative analytical approaches enabled the researcher to build a rich understanding of the children's interactions with CAPE V1. However, qualitative results would not be sufficient to establish whether the children were more likely to interact successfully with the virtual tutor when a synthetic voice or a

natural voice condition was used. This was achieved by using a quantitative analytical approach.

Quantitative data was extracted from video recordings of children's sessions (see Chapter 4, Section 3.3 for a detailed description). The data collected is summarised in this section and can be also be found in Appendix L.

Quantitative questions and hypothesis testing

Quantitative data collection of children's interactions with the virtual tutor was conducted during each of the voice type conditions. This was achieved by observing children's selection of symbols from four physical food and drink symbols stored in a PECS folder. During each (fixed-length) session the time the child spent looking at the physical symbols and the on-screen content was measured.

Five hypotheses were tested (measures associated with these hypotheses are discussed in Section 5.3 - quantitative data collection). Results from the literature provide differing views of the appropriateness of synthetic vs. natural voice in this context. Therefore, two tailed hypotheses were adopted for each of the measures as no prediction of direction could be made between the two conditions prior to testing.

Interpretation of the data was based on observations of each child's interactions with CAPE V1. Each observation and event was given an initial code to allow the researcher to highlight the data for further analysis.

Data was initially coded by two independent groups. The researcher coded the data from his notes and the transcripts of each session. Teachers were asked to comment on their interpretation of the sessions they had taken part in by watching

the video content. These two interpretations of the data were compared and any differences between the teacher's and the researcher's interpretations were discussed so that the researcher could gain a more in depth view of the children's behaviours.

This section presents the hypothesis for each of the five measures and discusses results from testing each of them. Results from each measure includes a summary of the raw data from both voice type conditions (see Appendix L).

1. The research investigated whether children selected more symbols correctly when exposed to a synthetic or natural voice condition. The research hypothesis predicted that there would be a difference between the number of symbols selected correctly when a virtual tutor used a synthetic and a natural voice alternative. The null hypothesis predicted there would be no significant difference in the overall number of correctly selected symbols between the natural and synthetic voice conditions. The dependent variable was the 'number of correctly selected symbols' and the independent variable was the virtual tutor's voice ('natural' or 'synthetic').

Table 5.8: number of correct responses per condition.

Condition	Total number of correctly selected symbols (food and drink symbols and Yes/No)
Synthetic voice	54
Natural voice	34

A Wilcoxon Signed-ranks test indicated that the synthetic voice condition elicited more correct symbol selections (Mdn = 6) than the natural voice condition (Mdn = 3.5), Z = -.2.207, p < 0.05, r= .78 in this two tailed test.

177

Therefore, the null hypothesis can be rejected (see Appendix M for more detail). When the total number of correctly selected symbols from each condition are considered, the results suggest that symbol selection was more successful when synthetic voice was used (see Table 5.8).

2. A comparison was made between the total lengths of time a child focused on the onscreen CAPE V1 content, or the symbols attached to the PECS folder. The researcher hypothesised there would be a significant difference between the lengths of time the children looked at the CAPE V1 screen, equipment and symbols during a synthetic or natural voice condition. The null hypothesis predicted there would be no significant difference in the length of time children looked at the CAPE V1 screen, equipment and symbols during a natural or synthetic voice session. The dependent variable was the total length of time the children looked at the computer screen and the symbols and the independent variable was the virtual tutor's voice type (natural or synthetic).

Table 5.9: Total time looking at CAPE V1

Condition	Total length of time spent looking at CAPE V1 (in seconds)
Synthetic voice	1595
Natural voice	1451

A Wilcoxon Signed-ranks test indicated there was no significant difference in the total length of time a child looked at CAPE V1 when synthetic voice condition (Mdn = 191.5) and natural voice conditions (Mdn = 164), $Z = -.840$, p 0.401 (two tailed), r= .29 were compared. Therefore, the null hypothesis cannot be rejected. These results suggest that voice type has no significant

influence on the length of time that a child spends looking at the CAPE V1 environment.

3. The length of time each child looked at the support teacher to either request help, or share the experience of using CAPE V1 was compared for synthetic and natural voice conditions observed over the session.

The hypothesis predicted there would be a significant difference in times between the two conditions. The dependent variable was the total length of time the child looked at the teacher and the independent variable was the virtual tutor's voice (natural or synthetic).

Table 5.10: Total time looking at the support teacher

Condition	Total time spent looking at support teacher (in seconds)
Synthetic voice	71
Natural voice	60

A Wilcoxon Signed-ranks test indicated there was no significant difference in the total length of time a child looked at the support teacher when synthetic voice condition (Mdn = 7.5) and natural voice conditions (Mdn = 5), Z = -.140 , p 0.889, r= .04 were compared in this two tailed test. Therefore, the null hypothesis cannot be rejected. This result suggests that voice type had no significant influence on the length of time a child will engage in social interaction (either as a way of getting help or sharing an activity).

4. A comparison was made between the total amount of time a child took to respond to virtual tutor requests when visual prompts were used during synthetic and natural voice conditions (for example, when images of symbols

179

representing the food and drink choices were shown at the beginning of the symbol selection task). The research hypothesis predicted that there would be a significant difference in the mean response time after a virtual tutor visual prompt when a synthetic or natural voice type was used. The null hypothesis predicted that there would be no significant difference in children's mean response time in either voice type condition. The dependent variable was the child's mean response time to onscreen visual prompting by CAPE V1 and the independent variable was the virtual tutor's voice type (natural or synthetic).

Table 5.11: Mean response times to visually prompted responses by CAPE V1

Condition	Mean time of response to virtual tutor request when a visual prompt was provided by CAPE V1 (in seconds)
Synthetic voice	6.13
Natural voice	38.25

A Wilcoxon Signed-ranks test indicated that the synthetic voice condition elicited significantly shorter mean response times when a visual prompt was used (Mdn = 5.5) compared with the natural voice condition (Mdn = 15), $Z = -2.521$, $p < 0.05$, $r = .89$ in this two tailed test. The null hypothesis could therefore be rejected. The large difference between synthetic and natural voice conditions can be attributed to David and Edward whose response times were significantly higher when natural voice was used by the virtual tutor compared to results by other children in the study (see Appendix L, Table L1).

5. A comparison was made between a child's response times to virtual tutor's verbal requests when a synthetic or natural voice was used and no attendant onscreen visual prompting was present. The null hypothesis predicted there

would not be a significant difference between the response time for natural and synthetic voice conditions. The dependent variable was the mean time a child took to respond to a virtual tutor's verbal request when no onscreen visual prompting was given and the independent variable was the virtual tutor's voice type (natural or synthetic).

Table 5.12: Mean response times when no prompt was given by CAPE V1

Condition	Mean time of response to virtual tutor request when no visual prompt was given by CAPE V1(in seconds)
Synthetic voice	1.58
Natural voice	5.49

A Wilcoxon Signed-ranks test indicated that the synthetic voice condition elicited shorter mean response times when no visual prompting given during a virtual tutor request (Mdn = 1.5) than in the natural voice condition (Mdn = 2.5), $Z = -2.028$, $p < 0.05$, $r = .71$ in this two tailed test. The null hypothesis could therefore be rejected.

5.5. Discussion

The pilot study had two major objectives: first to test CAPE V1 in terms of its 'proof of concept' and secondly to understand if voice type had any significant impact on user engagement and understanding. This section discusses the results from the pilot study in view of these two objectives.

Evaluation of the proof of concept

The main users of CAPE were non-verbal children with autism and it was not possible to elicit their preferences ahead of the design of a CAPE environment.

Children with autism are generally resistant to change and can become anxious when confronted with new situations. It was quite possible that the children would not take at all to the proposed system and may not have been willing to engage with it. For this reason it was essential to undertake testing of an early version of CAPE to observe behaviour and test reactions during use.

Evidence was sought to investigate:

1. the children's willingness and ability to interact with the virtual tutor using physical symbols linked through the RFID Bridge interface, and the children's associated behaviours (e.g. smiling, laughter, distraction or anxiety)
2. the potential for the children's communication development and learning
3. how CAPE V1 could be improved.

The following account describes how the 'proof of concept' objective was fulfilled.

Children's willingness and ability

Observations of the children's behaviour suggested that several aspects of CAPE V1 were of interest to them. One example was the virtual tutor verbal greeting accompanying the start of each session. When the virtual tutor said "hello" at the beginning of Session 1, each child turned to look at the CAPE screen. By Session 2, the children were increasingly focused on the screen prior to the virtual tutor's greeting and five of the children smiled when the virtual tutor waved to them.

Super Monkey clearly motivated the children in the pilot Study when used as reinforcement for selecting appropriate symbols during the food/drink selection tasks. When Super Monkey content was played seven of the children smiled, four of these children laughed and one child (although not smiling or laughing) clapped

his hands. Three children who pointed to the screen, may possibly have been attempting to share their experience of Super Monkey with the teacher. Both teachers involved in the pilot Study expressed their view that Super Monkey content was the main motivator for seven of the eight children. Henry was the exception. He seemed to find the virtual tutor very motivating and showed very little interest in Super Monkey.

Interaction with a computer using physical symbols had not been experienced by this group of children prior to the study. During the pilot Study exposure to the CAPE V1 system appeared to influence seven of the eight children to begin using verbal communication. Typically this took the form of echolalia or verbalising their choice of symbol. Verbal utterances may have been a way of a child instigating joint attention with the support teacher. The increase in social interaction was also identified in the Williams et al. (2002) study which also observed an increase in social interaction and speech use when a child used a computer system with support from a teacher.

Acceptance of the system by the children was demonstrated by all of the eight children involved in the pilot Study, each of whom attempted to interact with CAPE V1. In addition both teachers involved in the pilot Study expressed the view that CAPE V1 was very motivating for the children.

Potential for learning and communication development

The tasks that were included in the pilot study helped to ascertain whether the children's engagement using CAPE V1 could be beneficial to their learning and communication development.

To help the children learn to interact using symbols in this context the support teachers were asked to demonstrate the first iteration of each task (symbol selection, symbol tidy and Yes/No task) to the child at the beginning of Session 1 (known as task modelling). Once all of the tasks were modelled in this way, the child was invited to communicate with the virtual tutor themselves during the following Food/Drink selection task. Results suggest that teaching symbol interaction using a 'model and try' method was very successful with this group of children.

Children seemed to learn tasks that included verbal requests, visual cues and physical symbols more quickly than tasks that only had virtual tutor verbal output. Seven of the children were able to interact with the virtual tutor using symbols during food/drink selection and six children completed Yes/No tasks without support from their teachers by Session 2. Children's success in selecting food and drink symbols was probably based on previous experience of using PECS. The use of food and drink symbols by these children was confirmed by both support teachers prior to the study.

Both teachers reported that prior to the study none of the children had been exposed to the Yes and No symbols. Results show that six of the children were able to use the Yes symbol independently by Session 2. However, five of the children used the Yes and No symbols together when they wished to finish their session. This suggests that they did not understand the binary meaning of the Yes and No symbols, electing instead to use both symbols as a way of indicating their desire to finish the session. The selection of the Yes symbol to continue tasks was probably because the children had observed the teacher select Yes during the modelling phase. Finishing the session (selecting No) had not been demonstrated.

In addition, the visual cue associated with the Yes/No task was the Yes and No symbols shown together. It is possible that the five children who selected Yes and No were copying the symbols shown on screen when they wished to finish the task. When the support teachers were asked about the children's use of Yes and No, both teachers stated that the children were not familiar with the symbols and the teachers tended not to teach the children Yes and No until later in their PECS communication development. However, both teachers stated they had decided to teach the symbols (or variants of them) to the children in future.

Observations of children's interactions with CAPE V1 suggests that children found the 'tidy task' difficult to master. All eight of the children took longer to complete the tidy task (a task with no visual cue) compared to symbol selection tasks that had visual cues associated with them. However, as the children became more familiar with the CAPE tasks it is possible that a link between the need to complete symbol tidy to be allowed to select another symbol (a reward for completing the task) could have resulted in positive reinforcement for the tidy task. For example, four of the children (Brian, Alan, Charles and David) were able to complete the symbol tidy task by the end of Session 1. The tidy task was the only task that did not have an associated visual cue, so children had to rely solely on verbal prompting by the virtual tutor. Results suggest that the children were more successful in completing tasks that included an onscreen visual prompt (Food/Drink and Yes/No tasks) than when they were asked to complete a tidy task, which did not include visual prompts. This result suggests that these children depended on visual cueing to help reinforce the meaning of virtual tutor requests.

Evaluation of the influence of voice type on children's use of CAPE V1

The potential influence a voice type may have on a child's willingness to use a CAL system had been highlighted by the literature (Williams et al., 2004). However, results from quantitative analysis suggest that there was no significant difference in the total time the children spent looking at the computer screen and symbols (see Table 5.9) or looking at a support teacher when a synthetic or natural voice was used (see Table 5.10). Qualitative results suggest that Super Monkey content was well received and enjoyed by the children and may have influenced some instances of social interaction with the teacher. When quantitative and qualitative results are also considered it is possible that Super Monkey content had more influence on the time a child spent looking at the computer screen and symbols or looking at the teacher than the voice type used by the virtual tutor.

A comparison of children's mean response times to virtual tutor requests (containing visual prompting and unprompted tasks) showed that they were shorter during the synthetic condition compared to results from the natural voice condition. This result may be due to the lack of emotional output contained in the synthetic voice output which may have helped to reduce the processing of the utterance meaning by the child. These results suggest that synthetic voice has a positive influence on children's performance compared to the natural voice alternative (see tables 5.11-5.12).

Some of the children responded to a virtual tutor request that did not include a visual prompt (such as showing onscreen representations of symbols to select). Brian, Alan and Charles from Group 1 consistently responded to the symbol tidy

task (which has no visual prompt to remove the symbol from the reader). This result may also be due to the children identifying and responding to words or phrases that they identified as important in the virtual tutor's utterance. For example, the phrase "Super Monkey" was only used in symbol selection tasks and the word "remove" was only used in the symbol tidy tasks. If the children were relying on specific words and phrases in the sentence then it is possible that the utterances used in CAPE V1 were too long and future versions of CAPE V2 should ensure that virtual tutor utterances are short and consistent to allow the children to understand them better.

These results seem to agree with qualitative results from this study that suggests that virtual tutor requests were easier to understand when a synthetic voice was used.

5.6. Conclusion

Results from the pilot study suggest that key features of CAPE (such as an RFID-enabled physical symbol user input system; user rewards in the form of funny cartoon content and virtual tutor led activities) could potentially motivate non-verbal children to take part in learning activities. In addition, children's mean responses to the virtual tutor requests (both with and without the inclusion of on-screen visual prompting of the task) improved when the virtual tutor used a synthetic as opposed to a natural voice alternative. Findings from this study provided useful insights into CAL learning for this group of children, which later influenced the development and use of a teaching environment called CAPE V2 (described in the next chapter).

Chapter 6: Main study

6.1. Introduction

The research reported so far in this thesis has shown that non-verbal children with autism can learn to interact with a virtual tutor using physical symbols (see Chapter 5, Section 5.5). The results also suggested that CAPE could influence this group of children to initiate social interaction, due to its use of a three-way communication model (described in Chapter 4, Section 4.2 and Chapter 5, Section 5.4). However, previous versions of CAPE (CAPE Simulator and CAPE V1) were designed specifically to test system functionality rather than to teach symbol communication. Therefore, the aim of the main study was to test an improved version of CAPE (described here as CAPE V2) as a symbol-based teaching environment for non-verbal children with autism and to evaluate its effectiveness in this context.

The aim of CAPE V2 was to teach a curricular subject to non-verbal children with autism using the PECS pedagogy. The curricular subject CAPE V2 would address was based on lesson plans for the term and was informed by individual children's IEP learning targets. After some discussion with the host school it was decided that CAPE V2 would deliver lessons to improve counting skills using a PECS pedagogy.

This chapter presents the findings from a four-week study designed to investigate the following research questions using CAPE V2:

1. Can a Computer Assisted Learning (CAL) system be designed and implemented to support PECS pedagogy for the purpose of improving symbol communication and social interaction in non-verbal children with autism?

2. To what extent could such a system improve the communication and social interaction skills of non-verbal children with autism?

The following sections discuss the approach adopted for this study. The ethical procedures used in the pilot study (and described in Chapter 3, Section 3.5) were continued for the main study (see Appendix B for an example of the parental consent form used in the pilot and main study).

6.2. Research methods

This section describes the children and support teachers who participated in the main study, and the research design and the procedures adopted.

The study population consisted of five children with a formal diagnosis of autism and who were categorised by their statements of special needs as being non-verbal. The children and teachers who took part in this study were from an autism unit based in the same special educational needs (SEN) school that hosted the pilot study. However, none of the children or teachers who took part in the main study had also taken part in the pilot study. The study population consisted of four boys aged 9.3, 8.9, 9.4, 10.3 and one girl aged 9.2. The maximum level of expressive language of all the children was reported by the school as being of one-word utterances.

Each child was supported during CAPE V2 sessions by a support teacher. Five teachers who worked routinely with the children were recruited to provide educational support to the children during the study.

The children and teachers' identities have been protected in this thesis by anonymising the children's and teachers' names (see Chapter 3, Section 3.5). The study population consisted of the following participants:

Table 6.1: Participant pseudonyms

Child	Assigned support teacher
Jack	ST1
Hugh	ST2
Bill	ST3
Tim	ST4
Molly	ST5

An Individual Educational Programme (IEP) is routinely used to set learning objectives for children with Special Educational Needs (SEN) in the U.K. Teachers supporting the study provided a recent IEP assessment of each child's needs. IEP information provided an understanding of each child's communication difficulties and needs, and helped to set the level of learning support required at the beginning of the study.

The host school was asked to provide information on any medical impairment considered by the teachers to be a significant barrier to the use of CAPE V2 (or example, colour blindness, hearing or sight impairment and photosensitive epilepsy). None of the children in this group was reported by their teachers to have an impairment that, on face value, would affect their learning using CAPE V2. One

child was reported to have epilepsy; however, medical advice obtained by the school stated that the child's symptoms were not triggered by exposure to computers or television monitors and he had used computers as part of his normal curriculum in the past without incident.

Teachers reported that three of the children (Hugh, Tim and Molly) had problems understanding long verbal utterances, often only seeming to understand parts of the instruction they were given (typically the start or end of a sentence). This was reported in the children's IEP as an 'auditory processing impairment'. The language comprehension level for the children had been assessed to be between two and three words. Therefore, it was advised by support teachers that CAPE V2 utterances should be limited to short sentences during the study.

Children's motivation was identified as an issue for four of the children. Jack, Tim and Bill were identified as particularly difficult to engage in learning activities; Jack and Tim were reported to exhibit bouts of inappropriate behaviour which included tantrums and all three of the children tended to avoid taking part in lessons unless pressed to do so by their teachers. Molly refused to take part in tasks including numeracy lessons. To encourage the children to take part in CAPE V2 lessons each task was designed to provide engaging content (funny Super Monkey reward content) and counting lessons that were modified to address each child's specific learning needs.

Research design

The differing learning needs observed in children during the pilot suggested that teaching sessions would need to be adapted to support each child, using an iterative method of observation, assessment and intervention modification.

To enable the researcher to fully address the research questions (see Section 6.1) it was important that the main study research used a mixed methods approach to data collection and analysis. It was also important that the study took place in a natural teaching environment and that the approach should take advantage of the teachers' experience and knowledge of the children taking part in the study. After considering these requirements, it was decided that the main study would be based on the formative experimental research approach. (See Chapter 3, Section 3.2 for information on the formative experimental approach).

The main study consisted of the children's CAPE V2 sessions and teacher interviews (described in Section 6.3). The following data were collected:

- Video recordings of sessions using a miniature video camera situated to the left of the CAPE V2 environment (see Figure 6.1).

- Observations of children interacting with CAPE V2, recorded in hand-written field notes (see Chapter 3, Section 3.3 for further detail).

- Post session semi-structured interviews with support teachers (see Chapter 3, Section 3.3 for further details of the interview method used). Interview questions were derived from observations the researcher made during each session.

- Post study (five weeks after the end of the study) semi-structured interviews with support teachers to review students' progress (described in Section 6.3).
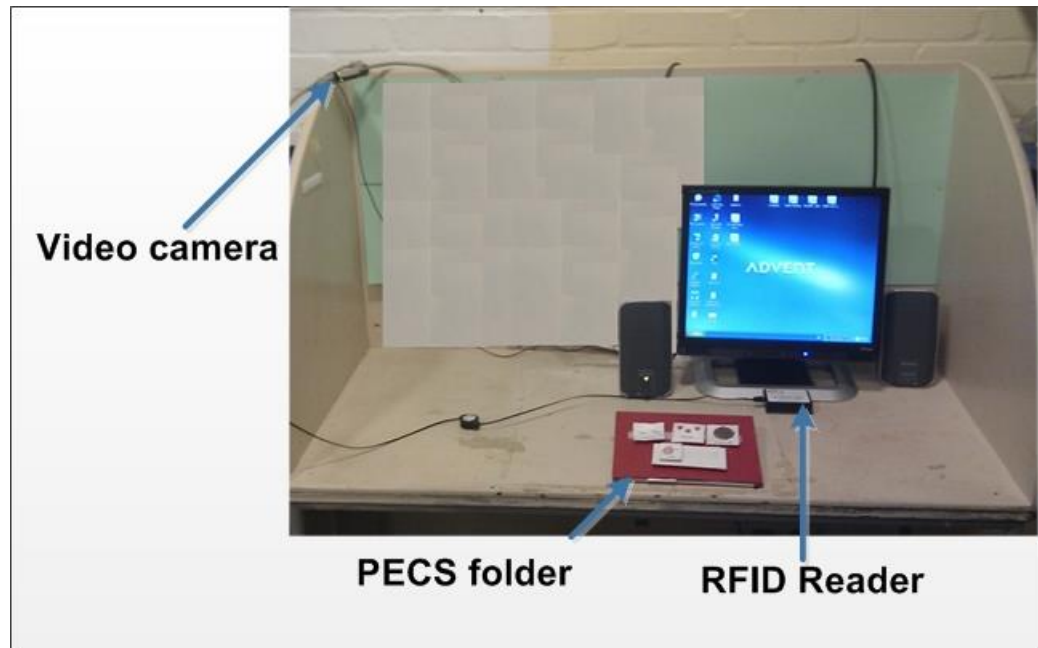
Figure 6.1: CAPE V2 layout

To gain a detailed understanding of the data, a mixed methods approach was adopted, which included quantitative and qualitative data collection and analysis.

Qualitative data was analysed using thematic and critical incident analysis in order to identify events of relevance to the research questions (see Chapter 3 Section 3.3).

The small and idiosyncratic nature of the population made parametric statistical analysis of the quantitative data an invalid option. A nonparametric statistical analysis was more appropriate for the sample size and the potential variation in response between children in this group, as was the case with the pilot study (see Chapter 5, Section 5.3). However, while the pilot study required an experimental comparison of two conditions, the requirements of the main study were to investigate the correlations between responses and symbol selection the child made and the session number as a way of measuring the progress of each child's interactions with CAPE V2.

Procedure

The host school had planned to use software applications to teach the children basic counting and arithmetic skills. After discussion with teachers from the school, it was agreed that the counting skills targeted in each child's IEP would be the educational focus during symbol communication lessons using CAPE V2. It was also agreed that children in the study could take part in addition and subtraction tasks using CAPE V2 if they were able to develop a counting strategy using CAPE V2.

Time constraints were encountered; these consisted of teacher availability and school schedules, influencing the length of the study and the number of sessions that would be conducted each week. To fit in with these constraints sixteen sessions were conducted over four weeks, involving each child in four sessions each week with a maximum of 10-minute duration for each session. Unfortunately, two of the children were only able to take part in fifteen of the sessions; Molly's parental consent form was not received until the morning of the second session and Tim was unwell and could not attend Session 12. However, these absences did not seem to have a detrimental influence on the two children's progress using CAPE V2, overall.

The teaching approach used in the main study was developed from: PECS teaching practices outlined in Frost & Bondy (2002); and results from the pilot study. CAPE V2 was designed to provide a consistent and repeatable virtual tutor-led lesson (described here as a task) which the child was asked to complete. Tasks were tailored to provide an individual learning design personalised to each child's learning needs, in the form of a student profile.

CAPE V2 taught new symbols and tested the child on symbols they had been taught in previous sessions. To teach children new symbols it was necessary to provide a task demonstration, where the child was able to see the virtual tutor select the correct symbol(s) for a given task, described here as a visual prompt. For example, Figure 6.2 shows a demonstration task being given to the child. In this example the virtual tutor asks the child "how many bricks does Super Monkey have?" The virtual tutor points to each of the bricks and counts each one in turn. Each brick is also made to stand out from the other bricks as it is counted to emphasise which brick is being counted and to keep the child focused on the counting sequence. Once all of the bricks have been counted virtual tutor states "I See ten bricks" and points to the sentence board which becomes populated with the I See and ten symbols (in sessions where the child was expected to use three symbol sentences the demonstration showed the symbols I See, ten and bricks to complete the full request.
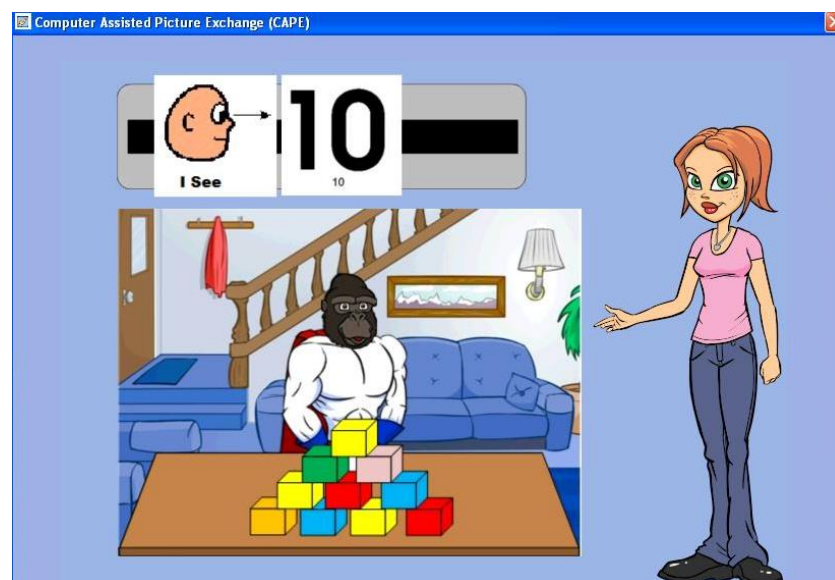
Figure 6.2: Virtual tutor demonstrates task with visual prompt

Correct symbol selection by the virtual tutor resulted in Super Monkey having a comic mishap (a visual reward). Once the child had been exposed to a task demonstration, the child was asked to carry out the same task themselves (see Figure 6.2).

It was also important to assess the child's ability to choose and use the symbols correctly to answer a virtual tutor question. For example, the virtual tutor asked the child to complete tasks from previous sessions to confirm if they were able to complete the task independently before the child could learn a new task.

Construction of replies to virtual tutor requests required the child to attach symbols to a board, known as the 'sentence board' (see Figure 6.3) and to place the sentence board on the RFID reader to complete the symbol exchange with the virtual tutor.
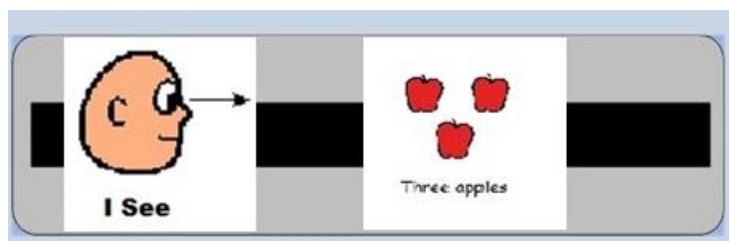
Figure 6.3: example of sentence board with a two-symbol sentence selection

Unlike the new symbol presentation, each test sequence did not include a task demonstration (see Figure 6.4).
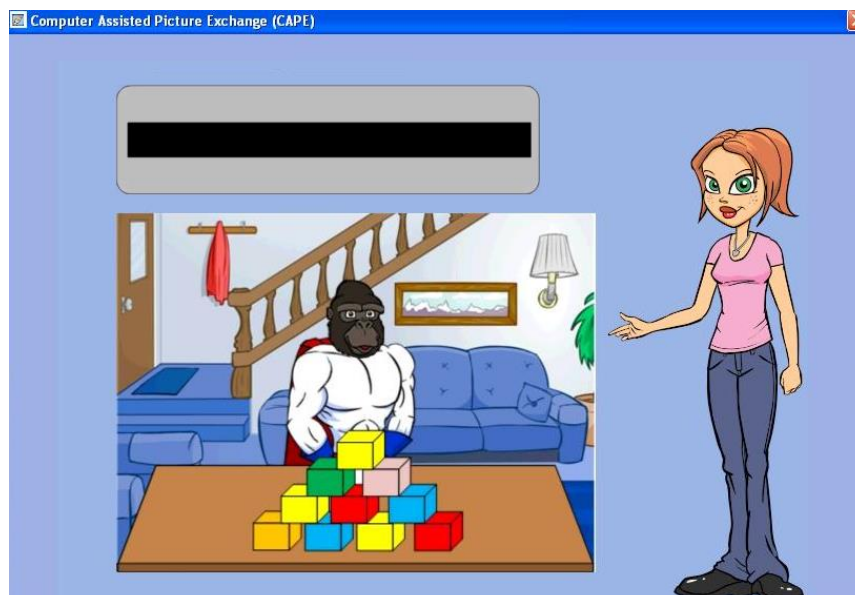
Figure 6.4: symbol selection task without onscreen visual prompt

Initially the children were given two chances to respond to each symbol selection task correctly. If they were unable to carry out the task using the correct symbol(s) in two exposures, a task demonstration was played. However, if a child was judged by the support teacher and researcher to have difficulty understanding symbol selection tasks then the child would be afforded greater support by reducing the number of symbol selection tries to one wrong answer, to provide a greater level of support from the virtual tutor, in line with PECS pedagogy. Once a child was able to select the correct symbol and respond appropriately correctly in response to a virtual tutor request the level of support was phased back, to allow the child to make two wrong answers before being corrected.

All selection tasks were accompanied by a 'symbol tidy' task similar to the one used in CAPE V1. During a 'symbol tidy', the virtual tutor asked the child to tidy the symbols (a phrase used in the school for removing symbols in PECS lessons). CAPE V2 waited until the child removed the symbols before continuing onto the next task.

Each child was assessed on their ability to use symbols correctly during the study. Assessments, combined with IEP information, and recent feedback and advice from support teachers based on observations in the child's most recent session, informed the choice of symbol type (digit or picture symbol) for each child (see Figure 6.5). Each child's symbols were stored in a dedicated PECS folder, made available to the child during each of their CAPE V2 sessions.
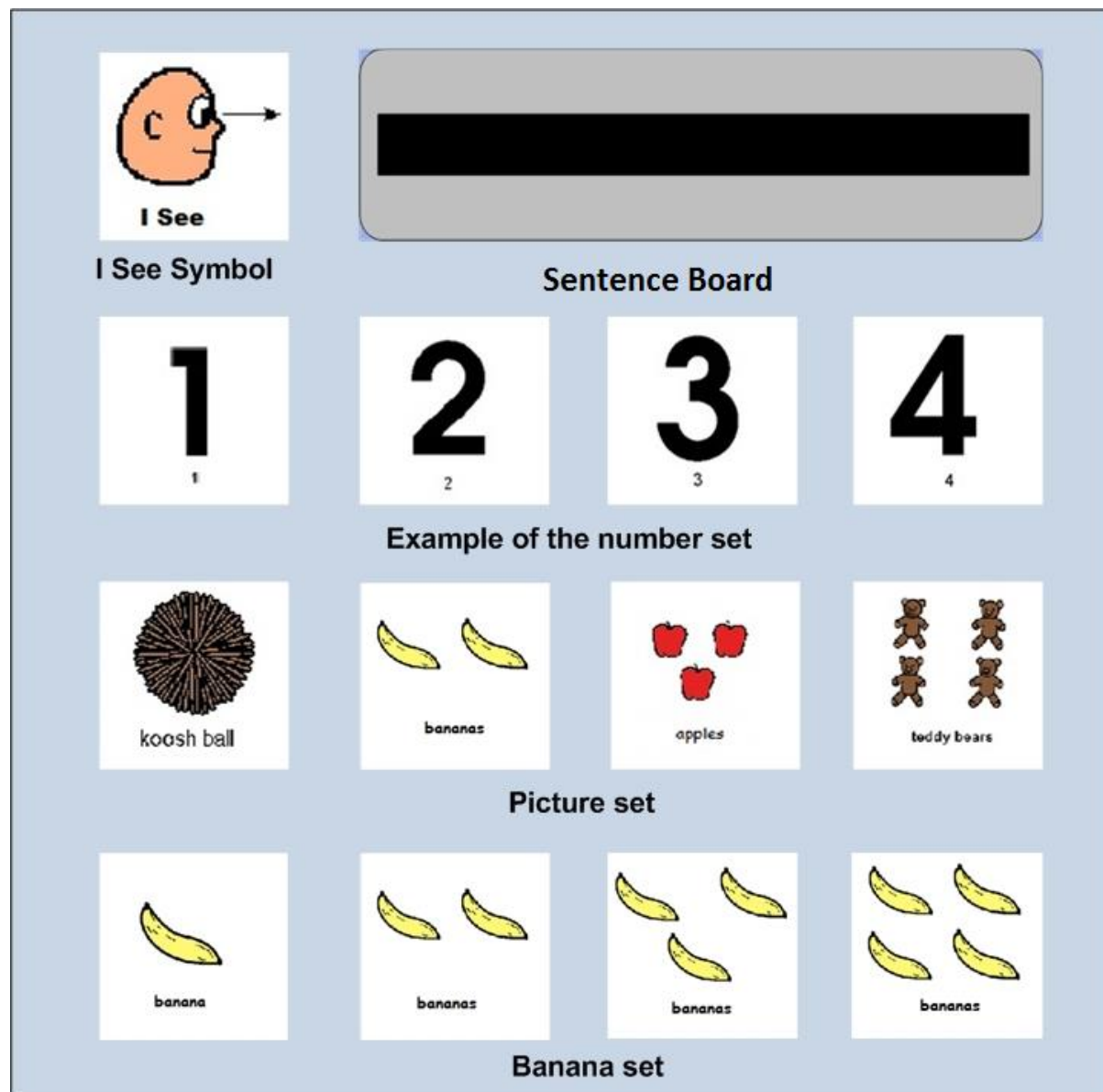
Figure 6.5: symbol set examples

The symbols fell into four basic symbol types (or sets) with examples shown in Figure 6.5. These were the following:

1. A number set which consisted of digit symbols. This set was used by four of the five children at the beginning of the study to assess if they had an understanding of digits and their abstract relationship with the quantity of objects. Children who successfully answered virtual tutor questions using digits were slowly introduced to a set of symbols ranging from digits 1 to 12.

2. The picture set consisted of simple line drawings of objects (described here as picture symbols). Each symbol presented a quantity of a particular object (four teddy bears were shown on a symbol representing four teddy bears). Children who did not have an understanding of digit symbols and their relationship to object quantity were given additional visual support in the form of picture symbols (see Figure 6.5). In Sessions 1 to 4, the children were asked to select a single digit or picture symbol to respond to the virtual tutor requests.

3. The banana set: this was a set of four symbols that represented quantities of one object type (in this case bananas). This set was slowly introduced to a child who was unable to use digit symbols (number set) to see if they were able to distinguish between different quantities of the same object type.

4. The 'I See' symbol: this was used with other symbols (either picture or a mix of digit and picture) to create two symbol sentences (for example I See banana. Children who were able to give two-symbol answers to virtual tutor requests were later encouraged to construct three-symbol sentences. An example of a three-symbol sentence is shown in Figure 6.6.

Figure 6.6: example of a three-symbol sentence selection

For a child to interact correctly with CAPE V2 in relation to counting skills and to answer the questions correctly in the tasks, the child needed to learn the following skills:

1. Follow the symbol procedure

    a. Select digit or picture symbol(s) (depending on the child's ability) from the symbol folder and attach the symbol(s) to a sentence board.

    b. Put the sentence board, with their chosen symbol(s) on to the RFID reader when the virtual tutor prompted the child to make a symbol selection.

    c. Remove the symbol(s) from the reader only when requested by the virtual tutor.

2. Make a correct selection of a symbol

    a. Look at the screen for visual prompts to symbol selection.

    b. Listen for verbal cues from the virtual tutor for symbol selection.

    c. Visually scan all of the symbols on the folder.

    d. Select the correct symbol from the PECS folder.

200

Study phases in detail

The study was broken into six stages. The stages were designed to help the children become accustomed to the CAPE V2 system and to teach counting and symbol communication following the PECS pedagogical approach.

This section describes the staged approach used in the study. Table 6.2 provides an overview of this process; and a more detailed discussion is given. The first stage (Session 1) was a group activity for the children with some children taking part in object matching and others in digit matching tasks; all subsequent stages/sessions were individual, involving just the child and their support teacher.

Table 6.2: main study session aims

Stage	Aim of stage	Session numbers	Task overview
1	Introduction to CAPE V2 system	1	Introduce digit or picture symbols (depending on child's learning needs) representing 1 item and items 2 (as a group session).
2	Familiarisation with CAPE V2	2 - 4	Increase the number of symbols taught to the child (digit or picture depending on ability) depending on observed success rate. The order of symbol presentation changed after each session and the child's progress was monitored.

Stage	Aim of stage	Session numbers	Task overview
3	Assessment of progress	5 - 6	An additional assessment of each child's progress based on each child's ability to interact with CAPE V2 and the number of symbols the child could use correctly without help from a support teacher over Sessions 1 - 6.
4	Adaptation of CAPE V2 to provide individual support for each child	7 - 8	Task and symbol modification for each child.
5	Introduction of sentence creation and new communication and numeric tasks	9 - 12	Encourage the child to create two or three symbol answers to virtual tutor questions and introduce additional symbol tasks to the child, depending on ability.
6	Assessment week (digits, picture symbols and banana set; see Figure 6.5)	13 - 16	Task type dependent on ability

1. In Stage 1 (Session 1), the children were introduced to CAPE V2 during a group session, with each child taking part in a five-minute introduction to the system. The remaining children were encouraged to watch the child's CAPE V2 session.

2. In Stage 2 (Sessions 2 – 4), the children were encouraged to become familiar with the CAPE V2 system; each child used CAPE V2 on a one-to-one basis supported by a teacher. Session lengths increased from 6 minutes in Session 2 to a maximum of 10 minutes in Session 4. Over Sessions 2 – 4, the number of symbols was increased from two in Session 2 to a maximum of four in Session 4, depending on the child's ability.

3. In Stage 3 (Sessions 5 and 6), each child's progress was evaluated. Prior to starting a session, the symbol exposure order was changed to see if the order of presentation, rather than understanding of the symbol representation, was responsible for selection. Other key indicators, such as reliance on visual prompts from task demonstration content and any other indications of a lack of understanding of the relation between a symbol and its meaning, were documented.

4. In Stage 4 (Sessions 7 – 8), CAPE V2 student profiles were modified to support each child's needs. For example, children who had difficulty using digit symbols were introduced to picture symbols to help them to build an understanding of symbol-based communication with the virtual tutor and to learn to match the object type on screen with the one pictured on the symbol.

5. In Stage 5 (Sessions 9 – 12), children with an understanding of the communication method employed by CAPE V2 were gradually introduced

to more symbols (digit or picture symbols depending on ability). Construction of phrases using 'I See' <digit or picture symbol> was also introduced. Children who were able to count onscreen objects using CAPE V2 were introduced to CAPE V2 addition and subtraction tasks. Subtraction and addition tasks showed Super Monkey with a quantity of a food type where some of the food was consumed or additional food was added. At the end of each session, each child's progress was assessed and learning objectives for the next session were agreed with the support teacher. Assessment was based on a comparison of the child's responses and symbol selection success in the recent and previous sessions to gauge the level of learning they have achieved with specific symbol selection and responses to virtual tutor requests over time. Changes were only made after consulting the support teacher working with the child concerned.

6. In Stage 6 (Sessions 13 – 16), children using picture symbols who had previously matched only object types (see stage 4), and who were considered ready to use picture symbols showing only one object type, were introduced to the 'banana set' (see Figure 6.5). The banana set was designed to teach children to match the number of objects on the screen with a similar number of objects shown on a picture symbol. The children were assessed on their ability to interact with the virtual tutor using the new symbols and to choose the correct symbols by comparing and matching similar quantities of the same object on screen and on the picture symbol. Children using digit symbols continued to increase their addition and subtraction skills. Any of the children who were still in the early stages of adopting symbol communication using CAPE V2 continued to use the system as they had in Sessions 9 – 12.

Six quantitative measures of the children's interaction with CAPE V2 were used, and a series of one-tailed hypotheses were tested. The hypotheses were designed to test children's responses to two task types: (1) the virtual tutor's 'symbol tidy' requests; (2) the virtual tutor's requests to select a symbol.

(1) A child's response to the symbol tidy task (the virtual tutor's verbal request to put symbols on the RFID reader back in the PECS folder) was judged to be one of the following:

- correct - if the child removed the symbol(s) from the reader and placed it/them in the PECS folder without support;

- incorrect - if the child did not complete the symbol tidy by (for example, throwing the symbol on the floor or giving it to the teacher);

- teacher-prompted - if the child did not react to the request within an elapsed time of ten seconds, and therefore a teacher prompt was required to help the child correctly complete the request.

 (2) A child's response to the virtual tutor's verbal request to select a symbol was judged to be one of the following:

- correct - if the child selected the symbol(s) required to answer the virtual tutor's request correctly;

- incorrect - if a symbol was selected that did not correctly answer the virtual tutor's request;

- Teacher-prompted - if the child did not respond to the symbol selection task after an elapsed waiting time of ten seconds, resulting in the teacher prompting the child to select the correct symbol.

The six hypotheses predicted that a relationship would exist between the following:

1. The number of times a child correctly responded to the symbol tidy task in each session and the number of sessions they had, so far, experienced. Correct response to a symbol tidy task required the child to take the sentence board (which included the symbols attached to it), take the symbols off of the sentence board and attach each of the symbols they had used to the PECS folder. The relationship between the number of times a child correctly responded to the symbol tidy task and the number of sessions the child took part in would be positive, suggesting an improvement in the child's ability to respond correctly to virtual tutor symbol tidy requests. The null hypothesis predicted there would be no relationship between the number of sessions and the number of correct symbol tidy responses a child made to virtual tutor requests.

2. The number of times a child responded incorrectly to virtual tutor requests to complete a symbol tidy in each session and the number of sessions they had, so far, experienced. An incorrect symbol tidy consisted of any action other than responses associated with a correct symbol tidy (see point 1), or not responding. The relationship would be negative, suggesting an improvement in the child's ability to correctly complete virtual tutor symbol tidy requests. The null hypothesis predicted there would be no relationship between the number of sessions and the number of appropriate responses to virtual tutor requests.

3. The number of times a support teacher was required to prompt a child to carry out virtual tutor symbol tidy requests in each session and the number

of sessions they had, so far, experienced. Teacher prompting only occurred if the child did not respond to the virtual tutor's request to remove the symbols from the reader after an elapsed time of ten seconds. However if teacher prompting was provided after the child had reacted incorrectly to the symbol tidy request (for example by placing a symbol on the reader) then the teacher prompt would be ignored and the initial response would be used (incorrect symbol tidy). The relationship would be negative, suggesting a decrease in the number of teacher prompts over sessions. The null hypothesis predicted there would be no relationship between the number of sessions and the number of responses by the child that required a teacher's prompt.

4. The number of times a child correctly selected symbols following virtual tutor requests in each session and the number of sessions they had, so far, experienced. For the response to be considered as 'correct', the child must select and place the correct symbol requested by the virtual tutor. The relationship would be positive, suggesting an improvement in the child's ability to select symbols correctly to virtual tutor requests. The null hypothesis predicted there would be no relationship between the number of sessions and the number of symbols selected correctly by the child.

5. The number of times a child incorrectly selected symbols following virtual tutor requests in each session and in each session and the number of sessions they had, so far, experienced. Incorrect symbol selection was defined as any action that did not constitute a correct symbol selection (point 4) or no response to the virtual tutor request. The relationship would be positive, suggesting an improvement in the child's ability to select

symbols correctly to virtual tutor requests. The null hypothesis predicted there would be no relationship between the number of sessions and the number of symbols selected correctly by the child.

6. The number of times a support teacher was required to prompt a child to make a symbol selection in each session and in each session and the number of sessions they had, so far, experienced. Teacher prompted symbol selection was defined as a prompting response (verbal or non-verbal) by the support teacher to help a child to select the correct symbol when they have not reacted to the virtual tutor's response. The relationship would be negative, suggesting that the number of teacher prompts decreased over sessions. The null hypothesis predicted there would be no relationship between the number of sessions and the number of teacher prompted symbol selections by the child.

To assess a child's ability to respond correctly to symbol tidy and symbol selection requests it was also necessary to calculate the percentage of times a child responded correctly to these tasks on a session-by-session basis over the length of the study. Results of the number of correct symbol tidy responses and correct symbol selection provide a clear view of children's success over sessions which can be compared with qualitative data to understand the reasons for specific peaks and troughs in children's observed behaviour. The results from the main study are presented next.

6.3. Results

This section reports results from qualitative and quantitative data collection from CAPE V2 sessions and from semi-structured interviews with teachers who supported children during the study. Observation data were analysed using qualitative and quantitative methods, and support teacher interviews were analysed using qualitative methods. This section provides results from quantitative data derived from video recordings and field notes of the children's CAPE V2 sessions. The section goes on to discuss qualitative data analysed using critical incident analysis, and thematic analysis was applied to post session teacher interviews.

Quantitative results

This section reports results from testing six hypotheses to gauge whether the children had learned new skills from their experiences of using CAPE V2. The section reports overall results of children's use of CAPE V2, followed by detailed results for individual children, for each of the six hypotheses (see the description of the research design in Section 6.2; see also Tables N1, N7, N8 and Figures N1 to N6 for study population results and Tables N2 – N6, Tables N9 to N18 and Figures N9 to N48 in Appendix N for a breakdown of participant results).

A Spearman's Rank Order correlation was run for each of the six hypotheses (see Chapter 3, Section 3.4, for a brief explanation of the Spearman's rank order correlation). These results are presented using the median (Mdn) and the interquartile range (IQR) to show the statistical distribution of the data, Spearman's rank correlation coefficient (or r_s) to show the statistical association between two variables (either as a positive or negative value) and the p value (p).

This section concludes with the results from an analysis of the data relating to symbol tidy and symbol exchanges undertaken by all of the children in each session (see Table N1) and by each child (Tables N2 – N6) in response to virtual tutor requests. This analysis presents the percentages of (1) correct responses to symbol tidy requests and (2) correctly selected symbols the children achieved during the study. Results from testing the six hypotheses are discussed next.

Testing Hypothesis 1: correct symbol tidy responses to virtual tutor requests

There was a significant association between the number of correct symbol tidy responses a child made to virtual tutor requests (Mdn = 59, IQR = 38.25 – 70.5) and the number of sessions they took part in (Mdn =8.5, IQR = 4.25 – 12.75, r_s = .870, p <0.01), which supports the research hypothesis that a relationship exists between these two variables. Also, this positive medium/strong result (r_s = .870) suggests that the number of correct symbol tidy responses to virtual tutor requests increased over sessions.

Analysis of each child's data show highly significant associations between the number of sessions and the numbers of correct symbol tidy responses for Hugh (Mdn= 9, IQR= 6.5 – 14.75, r_s =0.686, p< 0.01), Bill (Mdn = 13.5, IQR 9 – 15.75, r_s =0.824, p< 0.01) and Tim (Mdn = 8, IQR = 4.5 - 10.75, r_s =0.885, p< 0.01). Further, this association can be described as very strong (Cohen, 1988) for both Bill and Tim and strong for Hugh. However, Molly's and Jack's results are not significantly correlated with the number of sessions they took part in (see Table 6.3).

Table 6.3: The association between the number of times a child correctly responded to symbol tidy requests by the virtual tutor and the number of sessions they experienced

Children	Location of raw data	Location of data analysis	Mdn	IQR	P value	r_s
All participants	Table N1	Table N7 & Figure N1	59	38.25-70.5	<0.01	.870
Jack	Table N2	Table N9 & Figure N9	9	7-10.25	0.45	.030
Hugh	Table N3	Table N11 and Figure N17	9	6.5-14.75	<0.01	.686
Bill	Table N4	Table N13 and Figure N25	13.5	9-15.75	<0.01	.824
Tim	Table N5	Table N15 and Figure N 33	8	4.5-10.75	<0.01	.855
Molly	Table N6	Table N17 and Figure N41	15	9.25-19.75	0.12	.321

When individual results are considered, Hugh, Bill and Tim's results show that the null hypothesis can be rejected. However, Jack and Molly's results suggest that in this case the null hypothesis cannot be rejected. If all of the results from testing Hypothesis 1 are taken into account, it can be argued that three children in this group learned to respond correctly to virtual tutor symbol tidy requests over the length of the study.

Testing Hypothesis 2: incorrect symbol tidy responses to virtual tutor requests

There was a significant association between the number of incorrect symbol tidy responses a child made to virtual tutor requests (Mdn = 0, IQR = 0-7.7) and the number of sessions they took part in (Mdn =8.5, IQR = 4.25 – 12.75, r_s = -0.745, p <0.01), which supports the research hypothesis that a relationship exists between

these two variables. Also, this strong negative result (r_s = -0.745) suggests that the number of incorrect symbol tidy responses decreased over sessions.

Analysis of each child's data show highly significant associations between the number of sessions and the numbers of incorrect symbol tidy responses made by Jack (Mdn= 0, IQR= 0-0.5, r_s =-0.674, p< 0.01), Hugh (Mdn = 0, IQR 0-1, r_s =-0.787, p< 0.01) and Molly (Mdn = 0, IQR = 0-1.5, r_s =-0.655, p< 0.01). Further, this association can be described as a medium/strong and negative association for Jack, Hugh and Molly. Bill (Mdn = 0, IQR 0-1.5, r_s = -0.440, p = 0.04) and Tim's (Mdn = 0, IQR = 0-3.5, r_s = -0.465, p = 0.03) results are significant but have a weak negative association with the number of sessions they took part in, suggesting a very small decrease in incorrect symbol tidy responses over sessions (see Table 6.4).

Table 6.4: The association between the number of times a child responded incorrectly to a virtual tutor symbol tidy request and the number of sessions they experienced

Children	Location of raw data	Location of data analysis	Mdn	IQR	P value	r_s
All participants	Table N1	Table N7 & Figure N2	0	0-7.7	<0.01	-0.745
Jack	Table N12	Table N9 & Figure N10	0	0-0.5	<0.01	-.674
Hugh	Table N3	Table N11 and Figure N18	0	0-1	<0.01	-.787
Bill	Table N4	Table N13 and Figure N26	0	0-1.5	0.04	-.440
Tim	Table N5	Table N15 and Figure N 34	0	0-3.5	0.03	-.465
Molly	Table N6	Table N17 and Figure N42	0	0-1.5	<0.01	-.655

When individual results are considered, all of the children's results show that the null hypothesis can be rejected. Bill and Tim's results are significant to < 0.05. In addition three of the children's r_s are medium/strong, suggesting that the number of incorrect symbol tidy responses all the children made decreased as sessions increased. However, Bill and Tim's results show a weak negative association suggesting only a small decline in the number of times they incorrectly completed the symbol tidy task over the length of the study.

Testing Hypothesis 3: teacher prompted symbol tidy in response to virtual tutor requests

There was a significant association between the number of teacher prompted symbol tidy responses a child made to virtual tutor requests (Mdn = 0, IQR = 0 – 9.75) and the number of sessions they took part in (Mdn =8.5, IQR = 4.25 – 12.75, r_s = -.674, p <0.05). This supports the research hypothesis that a relationship exists between these two variables. Also, this strong/medium positive result (r_s = -.674) shows that the number of teacher prompts decreased over sessions, suggesting that the children required less prompting as sessions increased.

These results can also be considered from the perspective of each child's results (Table 6.5). Results suggest a strong and highly significant negative association between teacher prompted symbol tidy responses to virtual tutor requests and sessions for Jack (Mdn = 0, IQR = 0, r_s= -0.741, p = 0.01), Hugh (Mdn = 0, IQR = 0 – 2, r_s= -0.828, p < 0.01), Bill (Mdn = 0, IQR = 0, r_s= -0.654, p < 0.01), Tim (Mdn = 0, IQR = 0 – 1.75, r_s= -0.813, p < 0.01) and Molly (Mdn = 0, IQR = 0 – 3, r_s= -0.745, p < 0.01). Further, all of the children have a strong negative association between the number of times the support teacher was required to prompt the child and the number of sessions they experienced. This suggests that the number of

213

teacher prompts decreased over time. Therefore, based on these results the null

hypothesis can be rejected for all of the children's results.

Table 6.5: The association between the number of times a support teacher was
required to prompt the child to correctly carry out a symbol tidy in
response to a virtual tutor request and the number of sessions they
experienced

Children	Location of raw data	Location of data analysis	Mdn	IQR	P score	r_s
All participants	Table N1	Table N7 & Figure N3	0	0-9.75	<0.01	-.674
Jack	Table N2	Table N9 & Figure N11	0	0	0.01	-.741
Hugh	Table N3	Table N11 and Figure N19	0	0-2	<0.01	-.828
Bill	Table N4	Table N13 and Figure N27	0	0	<0.01	-.654
Tim	Table N5	Table N15 and Figure N 35	0	0-1.75	<0.01	-.813
Molly	Table N6	Table N17 and Figure N43	0	0-3	<0.01	-.745

Testing Hypothesis 4: correct selection of symbols in response to virtual

tutor requests

There was a significant association between the number of correct symbol

selections children made in response to virtual tutor requests (Mdn = 59, IQR =

38.25 – 70.5) and the number of sessions (Mdn = 48.5, IQR = 35 - 56) the children

took part in (Mdn =8.5, IQR = 4.25 – 12.75, r_s = .733, p <0.01). This supports the

research hypothesis that a relationship exists between these two variables. This

result also has a medium/strong positive association, suggesting that the number

of correct symbol selections increased as sessions increased.

Analysis of individual children's results show a highly significant association for Hugh (Mdn = 8, IQR = 5 – 14.75, r_s= 0.659, p < 0.01), Bill (Mdn = 8.5, IQR= 6 – 11.75, r_s=0.804, p < 0.01), Molly (Mdn = 12.5, IQR = 8 – 17.5, r_s=0.581, p= 0.01) and Tim (Mdn = 6.5, IQR = 8 – 17.5, r_s=0.471, p = 0.03) between the number of correctly selected symbols in each session and the number of sessions. Further, Bill, Hugh and Molly's results suggest there is a strong association, while Tim's results had a significant but relatively weak positive association, suggesting a small increase in the number of correctly selected symbols over sessions. However, Jack showed no significant improvement over sessions (see Table 6.6).

Table 6.6: The association between number of symbols the children selected correctly and the number of sessions they experienced

Children	Location of raw data	Location of data analysis	Mdn	IQR	P value	r_s
All participants	Table N1	Table N8 & Figure N4	48.5	35-56	<0.01	.733
Jack	Table N2	Table N10 & Figure N12	7	6-10	0.40	.063
Hugh	Table N3	Table N12 and Figure N20	8	5-14.75	<0.01	.659
Bill	Table N4	Table N14 and Figure N28	8.5	6-11.75	<0.01	.804
Tim	Table N5	Table N16 and Figure N 36	6.5	3.5-8	0.03	.471
Molly	Table N6	Table N18 and Figure N44	12.5	8-17.5	0.01	.581

Results from individual children (see Table 6.6) suggest that the null hypothesis can be rejected on the basis of Hugh, Bill, Tim and Molly's results. However, Jack's results suggest there is no significant correlation between the number of Jack's correctly selected symbols and the number of sessions he experienced.

Testing Hypothesis 5: incorrect symbol selection in response to virtual tutor requests

There was no significant association between the number of incorrect symbol selections in response to virtual tutor requests a child made (Mdn = 10.5, IQR = 8-15.5) and the number of sessions they took part in (Mdn =8.5, IQR = 4.25 – 12.75, r_s .331, p = 0.29). This result supports the argument posited by the null hypothesis that no relationship exists between the number of incorrect symbol selections a child makes and the number of sessions they take part in.

Analysis of each child's data show highly significant associations between the number of sessions and the numbers of incorrect symbol selections for Bill (Mdn= 4, IQR= 0.5-8, r_s =-0.587, p< 0.01), Tim (Mdn = 3, IQR 1-4, r_s =-0.680, p< 0.01) and Molly (Mdn = 0.5, IQR = 0-2, r_s =-0.584, p= 0.01). Further, this association can be described as a medium negative association for Bill, Tim and Molly. Jack (Mdn = 1, IQR 0-1, r_s = 0.298, p = 0.13) and Hugh's (Mdn = 0, IQR = 0-3, r_s = 0.019, p = 0.47) results had no significant association between the number of incorrectly selected symbols and the number of sessions they took part in (see Table 6.7).

Table 6.7: The association between the number of incorrectly selected symbols the children selected and the number of sessions they experienced

Children	Location of raw data	Location of data analysis	Mdn	IQR	P value	r_s
All participants	Table N1	Table N7 & Figure N5	10.5	8-15.5	0.29	.331
Jack	Table N1	Table N9 & Figure N13	1	0-1	0.13	.298
Hugh	Table N2	Table N12 and Figure N21	0	0-3	0.47	.019
Bill	Table N3	Table N14 and Figure N29	4	0.5-8	<0.01	-.587
Tim	Table N4	Table N16 and Figure N37	3	1-4	<0.01	-.680
Molly	Table N5	Table N18 and Figure N45	0.5	0-2	0.01	-.584

Testing Hypothesis 6: teacher prompted symbol selection in response to virtual tutor requests

No significant association was found between the number of times a teacher prompted a child to make a symbol selection in response to virtual tutor requests (Mdn = 0, IQR = 0.25-6.5) and the number of sessions they took part in (Mdn =8.5, IQR = 4.25 – 12.75, r_s = -.170, p= 0.26). This result supports the null hypothesis that a relationship does not exist between the numbers of teacher prompted responses a child received and the number of sessions they took part in.

Analysis of each of the children's results show a highly significant negative association between teacher prompted symbol selection to virtual tutor requests and the number of sessions for Jack (Mdn = 0, IQR = 0-1.75, r_s= -0.562, p = 0.01), Hugh (Mdn = 0, IQR = 0, r_s= -0.434, p = 0.04) and Bill (Mdn = 0, IQR = 0, r_s= -0.503, p = 0.02). Further, Jack and Bill's results had a medium negative

association and Hugh's had a weak negative association between the number of times the support teacher was required to prompt the child and the number of sessions they experienced. This suggests that the number of teacher prompts decreased over time. These results suggest that the null hypothesis can be rejected for three of the five children's results.

Table 6.8: The association between the number of times a support teacher was required to prompt the child to make a symbol selection and the number of sessions they experienced

Children	Location of raw data	Location of data analysis	Mdn	IQR	P score	r_s
All participants	Table N1	Table N8 & Figure N6	3	0.25-6.5	0.26	-.170
Jack	Table N2	Table N10 & Figure N14	0	0-1.75	0.01	-.562
Hugh	Table N3	Table N12 and Figure N22	0	0	0.04	-.434
Bill	Table N4	Table N14 and Figure N30	0	0-1	0.02	-.503
Tim	Table N5	Table N16 and Figure N 38	0.5	0-3.75	0.43	-.043
Molly	Table N6	Table N18 and Figure N46	0	0-1.75	0.13	-.311

Children's success using CAPE V2 measured as percentages

The children's success in using CAPE V2 was analysed further to investigate the change over sessions in their ability to (1) respond correctly to the symbol tidy task and to (2) correctly select symbols in response to virtual tutor requests.

For (1) this was achieved by calculating the total number of symbol tidy responses (correct, incorrect and teacher prompted) for all of the children's results in Table N1 and then calculating the percentage which were correct. A similar method was used for (2) to calculate the percentage of correct symbol selections for all of the children in the study. Percentage scores for both measures (correct symbol tidy and correct symbol selection) were also calculated for each child, individually (see Table N2 – N6).

The results suggest that the children's ability to respond correctly to symbol tidy tasks in response to virtual tutor requests show a marked improvement from 43% in Session 1 to 100% of responses from Session 8 onwards (see 'percent correct symbol tidy' in Figure 6.7).
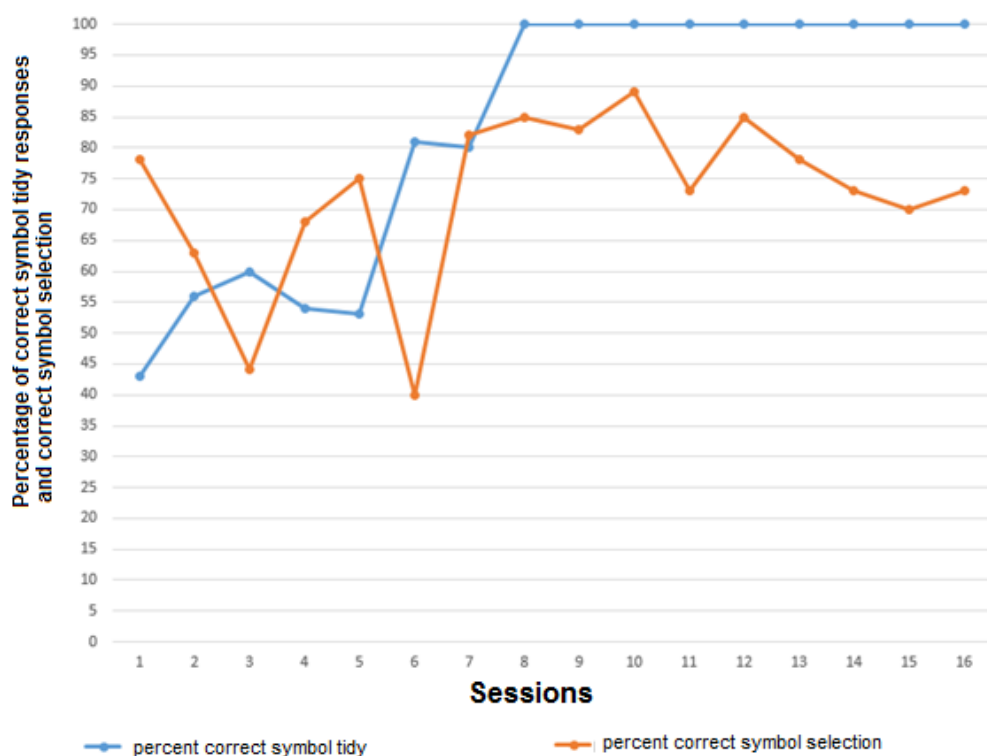
Figure 6.7: Percentage of correct symbol tidy responses and correct symbol selection for all users

Results for correctly selected symbols are generally lower than results for correct responses to symbol tidy, with dips overall in performance being experienced in Sessions 3, 6 and 11 when new tasks were added to the teaching sessions. There was a gradual decline in success from 85% (Session 12) to 70% (Session 13) (see 'percent correct symbol selection' in Figure 6.7). This result was influenced by the introduction of the 'banana set' to Hugh and Molly, subtraction tasks for Jack and new counting tasks for Bill and Tim in Sessions 13 – 15. A slight increase is seen in Session 16 when the children only completed the tasks they had seen in Session 15, to allow them to consolidate their understanding of the tasks (see Figure 6.7).

When each child's correct symbol selection results are compared it is clear that Molly and Hugh made the most progress over sessions. Both children experienced difficulty using digit symbols early in the study (Sessions 2 - 6). However, after digit symbols were replaced with picture symbols a large increase in correct symbol selection was achieved. For example in Session 6 Molly correctly selected symbols 15% of the time, however, in Session 7 this increased to 100% and remained at 80% - 100% for the remainder of the study (see Table N6 and Figure N48). Hugh achieved similar results with a low score of 17% of correct symbol selections in Session 6 and rising to 100% in Session 7 to 13. However, Hugh did have a small decline in symbol selection success in Sessions 14 to 16 when he was actively using the banana set (see Figure N24).

Bill's ability to select the correct picture symbol fluctuated between low success in Sessions 1, 6 and 12 when he was introduced to new symbols and high points in Sessions 4 and 5, when he selected all of his symbols correctly (100%). He

achieved 60-86% success over the remaining sessions (see Table N4 and Figure N30).

Jack's symbol selection success also varied, with initial high success (100%) in Sessions 1 and 2 but marked declines when new symbols and different skills were introduced. For example in Session 11 Jack was introduced to new addition tasks and in Sessions 13 - 16 he was asked to complete subtraction tasks. These new challenges had an influence on his ability to correctly select digit symbols (see Table N2 and Figure N16).

Quantitative results suggest that children's results may be based on the children's specific learning needs and the success with which CAPE could be adapted to meet their needs. However, to understand the reasons for rises and declines in a child's ability to select a symbol correctly, it is necessary to consider their responses from a qualitative perspective, which is discussed next.

Qualitative results

This section reports qualitative results from observations and semi-structured interviews conducted during the research. Results from video recordings and observation notes of sessions have been analysed from two perspectives; important themes that emerged from the data (identified using thematic analysis) and incidents that reflect important changes in the way the children interacted with CAPE V2 (identified using critical incident analysis). Semi-structured interviews conducted with support teachers were analysed using a thematic analysis approach.

The results are presented here as follows:

- Thematic analysis of children's progress during sessions

- Critical incidents

- Thematic analysis of post study teacher interviews

Thematic analysis of children's progress during sessions was derived from video recordings, researcher field notes and teacher interviews that were conducted after each CAPE V2 session. Observational data was also analysed for signs of critical incidents, to provide the researcher with child progress data and a critique of the interventions' effectiveness in a session. Results from thematic analysis and critical incident analysis were compared to create a richer understanding of each child's learning, and learning needs, and to highlight required intervention improvements.

Five weeks after the study had finished the researcher conducted a series of post study interviews with the teachers who had supported the main study. This allowed the researcher to gather information on the long-term impact of the intervention. The results from this study are discussed next.

Thematic analysis of children's progress during sessions

Collection of data was achieved by video recording each CAPE V2 session. Researcher observations were recorded in field notes as a precaution against any loss of data that might result from hardware failure of the video recording equipment. At the end of each session the teacher's observations were recorded in a semi structured interview. At the end of each research week all of the captured data from videos, notes and teacher interviews were reviewed and analysed using a thematic analysis approach.

This section presents the results from analysing these sources. The following themes emerged from the data (see Table 6.11). These themes are described in more detail next.

Table 6.11: Themes relating to CAPE V2 sessions

Theme number	Theme description
6.1	Visual scanning of symbols increased selection accuracy
6.2	Picture symbols support early use of symbol communication
6.3	Children smile and laugh when Super Monkey content is played
6.4	Children vocalise when Super Monkey content is played
6.5	Children initiate social interaction with the support teacher

Theme 6.1 – Visual scanning of symbols increased selection accuracy

Adoption of a symbol selection strategy that included looking at all of the symbols in the PECS folder before the final symbol selection increased the children's success in answering tasks correctly. However, some children did not adopt this symbol selection strategy. This resulted in a higher number of incorrect selections by the child.

Jack – Session 8 video observation: "The request to count two different fruit (two bananas and three apples) as an addition task is not reacted to straightaway. [Jack] pauses and then looks toward the support teacher; He seems to think about which symbol he will need, first scanning the PECS folder. He looks back at the folder, selects 5, places the symbol on the comm. Board and places the Sentence Board on the reader"

Hugh – Session 4 Field note: "as soon as virtual tutor states "Super Monkey has some apples" [Hugh] looks at the PECS folder and then snatches symbol 3 and places it on the reader (correct answer)"

Hugh – Session 4 teacher interview: "when [Hugh] bothered to look at the folder he did get some of the symbols right."

Bill – Session 11 video observation: "Virtual tutor introduces 5 toy cars. When virtual tutor asks how many toy cars there are [Bill] points to the screen to prompt counting, the teacher verbalises [digits] and [Bill] points to each of the objects as she counts (892.43). [Bill] scans the symbols on the folder and then selects 5 from the folder, placing on the reader"

Tim – Session 7 Field note: "[Tim] looks at the screen until virtual tutor shows him the three apples symbol. Tim looks down to the PECS folder and scans the symbols, touching the 3 apples symbol. He looks up again at the 3 apples symbol on the onscreen sentence board possibly checking to see if he has the right one and then selects 3 apples and places it on the reader"

Tim – Session 7 teacher interview "well, you know I am amazed by how well [Tim] worked today! It all seemed to click once he started to look at the symbols on the computer and in his [PECS] folder. He has made more progress today than I have seen him do before, it is amazing"

Molly – Session 7 video observation: "[Molly] seems a little more relaxed now. She looks at the bananas on screen and then down to the folder, looking intently at each symbol in turn. When she looks at the 2 bananas symbol she looks up at the screen and then down at the symbol. [Molly] selects the symbol quickly and places it with both hands on the reader"

Theme 6.2 – Picture symbols support early use of symbol communication

Initial use of digit symbols in the CAPE V2 sessions had a negative influence on some children's ability to answer virtual tutor requests. However, replacement of digit symbols with picture symbols depicting different numbers of specific objects proved more successful than digit symbols for children who did not understand the relationship between digits and quantities they represent.

Molly – Session 7 teacher interview: "the picture symbols have really helped. I think the numbers [digits] were too confusing for her but now she really seems to be getting the hang of it [CAPE V2 with picture symbols]. I will be really interested to see how she gets on tomorrow"

Hugh – Session 7 Field notes: "[Hugh] has become more successful at selecting symbols correctly [matching physical symbol on the screen with a similar symbol shown as onscreen content] now he uses picture symbols. He seems to understand how to interact with picture symbols. He seems to be matching object types rather than the number of objects rather than having a counting technique"

Hugh – Session 7 teacher interview: "[Hugh] seems to be getting the hang of it now. I was worried when we found that he was just following the presentation order that we wouldn't get any further but he seems to be really making progress now"

Molly – Session 8 video observation: "Now [Molly] is using picture symbols she is able to select symbols correctly for each task in her session."

Tim – Session 7 video observation: "Tim has started to become aware that the correct symbol can be found by matching the object on the screen with the object on the picture symbol. By learning this technique Tim has become more able to choose symbols correctly and receive the Super Monkey reward content"

Theme 6.3 – Children smile and laugh when Super Monkey content is played

Animation showing Super Monkey performing comic acts seemed to be very popular with all five of the participants. All five of the children smiled and laughed when Super Monkey was shown on screen.

Hugh – Session 1 video observation: "[Hugh] begins to smile and laugh when Super Monkey is animated. [Hugh] begins to look both at the screen and the folder, showing good scanning skills"

Bill – Session 7 video observation: "as the comic sequence starts [Bill] looks at the screen and smiles. He seems to like the crash sequence. [Bill] starts to laugh. "

Tim – Session 7: "When the Super Monkey content starts [Tim] looks from the symbols on the reader to the screen. When Super Monkey bounces the koosh ball, he smiles and then begins to laugh. He is focused on the screen and does not look away until the content has finished"

Bill – Session 7 teacher interview: "Bill really likes Super Monkey doesn't he? I think that having the monkey as a reward has really helped him to stay interested in the tasks"

Molly – Session 12 field note: "Molly smiles when she sees Super Monkey pick up the banana [1 banana task]. When the banana is splats into his face she begins to laugh and point to the screen saying "mookie" and laughs again".

Theme 6.4 – Children vocalise when Super Monkey content is played

Three of the five children used verbal output during Super Monkey content. This ranged from early speech use like 'mo, mo' to 'mookie' by one child.

Hugh – Session 9 video observation: "When Super Monkey is told off for breaking the window in the [Super Monkey reward] content [Hugh] vocalises ("ba, ba")"

Molly – Session 8 video observation: "As Super Monkey begins the 5 toy cars reward content Molly smiles and points to the screen saying "Mookie" The teacher looks at [Molly] and laughs, saying "did you say Monkey?""

Molly – Session 8 teacher interview: "You know I couldn't believe it. She actually said monkey…it wasn't clear and at first I thought I had imagined it."

Tim – Session 7 field note: "Super Monkey appears on the screen as CAPE begins the welcome phase at the beginning of the session [Tim] points at Super Monkey and says "mo, mo, mo" possibly trying to say monkey"

Theme 6.5 – Children initiate social interaction with the support teacher

All five children initiated social interaction with the support teacher during CAPE V2 teaching sessions. Social interaction could be initiated by the child by asking for help, and to share their enjoyment of using CAPE V2 with their support teacher as sessions increased. However, the main focal point of social interaction related to the actions of Super Monkey during the reward content rather than in response to virtual tutor verbal requests.

Jack – Session 1 teacher interview: "[Jack] is normally in his own world and doesn't really try to interact with others but he did try today […] Yeh, I think he wanted help"

Jack – Session 14 video observation: "When virtual tutor asks [Jack] to select bricks he turns to the support teacher and verbalises "d, d", He tucks his hands to his chest, he seems to be asking to finish now"

Jack – Session 14 teacher interview: "yes, I think he is being more social than he used to be. It still isn't all the time but at least he is asking for help more now"

Hugh – Session 3 video observation: "[Hugh] really enjoys the cheering that is played at the beginning of the reward content. When he hears it he smiles, laughs and looks to the teacher to share the experience (302.48)"

Bill – Session 3 video observation: "[Bill] selects 3 from the folder (correct) and smiles at the screen. He looks at the teacher and smiles".

Tim – Session 8 video observation: "Tim puts the 3 apples symbol on the reader and turns to the teacher and smiles. When Super Monkey appears he turns and points to Super Monkey to share the experience with the support teacher"

Molly – Session 14 field note: "as the Super Monkey reward clip starts [Molly] looks at the teacher and smiles, saying "mookie"

Thematic analysis and its importance in a mixed methods approach

Thematic analysis provided a rich understanding of the data from the perspective of the children's behaviour and the way they interacted and communicated with the virtual tutor and the support teacher over sessions. However, it was also important to gain an understanding of the factors and reasons for this change. This was achieved using critical incident technique (see Chapter 3, Sections 3.4 and 3.5) which is discussed next.

Critical incidents

Important changes in the children's behaviour over sessions were recorded as 'critical incidents' and these incidents are reported in more detail next. The following critical incidents, reflecting important changes in the way children interacted with CAPE V2. These critical incidents were identified using the critical incident technique described in Chapter 3, Section 3.4 and Section 3.5.

Critical incidents are reported in the order in which they were observed and will be discussed next.

- Unaided symbol tidy

- Unaided symbol selection

- Visual scan of the symbol folder prior to symbol selection

- Adoption of picture symbols

- Unaided counting

- Unaided addition and subtraction

Unaided symbol tidy

Four of the children (Jack, Hugh, Bill and Molly) completed their first independent symbol tidy in Session 2. They continued to complete symbol tidy over the remainder of the sessions without help from their support teachers. Tim did not complete his first independent symbol tidy until Session 7; once Tim had become accustomed to the symbol tidy task in session 7, he continued to complete the task unaided for the remainder of the study.

Unaided symbol selection

Independent symbol selection was completed for the first time by Jack at the end of Session 1. Molly pointed to a symbol in her first session (Session 2) and went on to select and place the symbol on the reader in her second session (Session 3). Hugh and Bill completed their first unaided symbol selections near the end of Session 2. However, Tim did not complete his first unaided symbol selection until Session 7. Each of the children continued to make independent symbol selections without help from a support teacher for the remainder of the study.

In Sessions 1 - 12, Hugh and (Sessions 2 -12) Molly had been exposed to symbols with objects that represented specific quantities. For example, the three apples task was the only task used to count three objects and no other denomination of apples was tested during these sessions. However, in Sessions 13 to 16 of the study Hugh and Molly were slowly introduced to symbols depicting only one object type, known as the 'banana set (see Figure 6.5). Hugh and Molly were both able to select banana set symbols 1, 2 and 3 bananas correctly in Session 14, when four objects were still being represented by 4 teddy bears. When 4 teddy bears was replaced by 4 bananas in session 15 both Hugh and Molly initially seemed to have problems differentiating between 3 and 4 bananas during tasks. However, by the second iteration of the 3 and 4 banana tasks both Molly and Hugh were able to distinguish between these symbols.

Visual scan of the symbol folder prior to symbol selection

At the beginning of the study, three of the children (Bill, Tim and Molly) did not take time to look at the symbols in their symbol folder before choosing the symbol to answer tasks (described here as making an informed choice). Molly and Bill completed their first visual scan of symbols in the symbol folder in Session 2. Molly

continued to improve her symbol scanning ability by taking time to check each symbol against the symbol shown in the demonstration clip over Sessions 2 and 3. Bill took longer to develop a scanning strategy but slowly improved his selection successes over Sessions 5 to 7 until he was consistently selecting correct symbols by Session 8. Tim made his first visual scan of the symbol folder in Session 7, coinciding with his first correct symbol selection.

Adoption of picture symbols

Hugh and Molly found digit symbols difficult to use and often made mistakes that seemed to cause them distress. To support Hugh and Molly's learning needs picture symbols (shown in Figure 6.5) were introduced as a replacement for digit symbols in Session 7. Both Hugh and Molly very quickly became able to select the correct symbol by the end of Session 7.

Unaided counting

Bill first demonstrated independent counting of objects on the screen in Session 11. This developed from the 'counting with teacher' support given in Session 6. Bill continued to use this technique over Sessions 12 to 16 independently.

Unaided addition and subtraction

Jack was the only child in the study to complete addition and subtraction tasks. These were as follows:

Jack was introduced to addition tasks in Session 9. By the end of Session 9, he had completed his first addition task without any support from his teacher.

Jack was introduced to subtraction tasks in Session 9. Initially he found subtraction very difficult.

Post-study teacher interviews

At the end of the study, teachers at the host school expressed the view that CAPE V2 had been a very useful teaching tool and it was agreed that the host school could continue using CAPE V2. Five weeks after the completion of the main study, the researcher visited the host school to conduct semi-structured interviews with the teachers who had taken part in the main study (see Appendix P for an example of the interview schedule). Unfortunately, one of the five teachers (ST5) had left the school, so only four of the five teachers were available for interview.

Each interview was conducted over a maximum of 30 minutes and was recorded using a Dictaphone. The researcher also took notes as a backup for any issues with the recording device.

Prior to each interview the researcher explained the aim of the interview, the rights of the interviewee and gained permission from the interviewee to take part in the interview.

 The interview focused on the following discussion points:

1. Children's communication and counting ability prior to the study
2. Children's progress during the study
3. Experience of using CAPE V2 after the study
4. Advantages and disadvantages of using CAPE V2

Data collected from the interviews were analysed using thematic analysis (see Section 6.2 and Chapter 3, Section 3.3). A summary of findings from the analysis follows and includes quotes of important statements by interviewees.

Discussion point 1 – the children's communication and counting ability prior to the study

The support teachers were asked to describe each child's ability to communicate and complete counting tasks prior to the study. Analysis of teacher's answers resulted in the following themes:

Table 6.12: Themes relating to children's communication and counting ability prior to the study

Theme number	Theme description
6.6	PECS was the only communication method for the children
6.7	Counting skills had not developed prior to the study

Theme 6.6 - PECS was the only communication method for the children

Prior to the study, all of the children in the study had used PECS symbols as their primary communication method. Symbol communication was difficult for Tim and Bill because they did not look at symbols sometimes during PECS lessons. Jack rarely interacted with teachers and Molly tried to control her interactions with others and often said 'no' when asked to take part in activities. Teachers made the following observations:

ST1: "[Jack] uses PECS to communicate. He rarely interacts with people but when he does he does not speak."

ST3: "[Bill] is not verbal at all. He uses PECS in class but can be quite lazy and it is quite difficult to motivate him to use his symbols"

ST4: "[Tim] uses a few symbols to communicate. He can't speak and often gets confused when I ask him to do something."

Theme 6.7 – counting skills had not developed prior to the study

The support teachers said that only one of the children in the study (Jack) could count independently prior to the study. Tim did not really understand the concept of counting and Molly would refuse to count. All of the children lacked motivation when counting was being taught. Teachers stated the following:

ST1: "[Jack] could complete basic addition tasks but wasn't able to complete subtraction tasks when he used 'geofix cubes'".

ST2: "Well, when I first worked with [Hugh] he seemed to be able to count to four by matching [digits] to groups of toy cars, but I can see now that he probably didn't really understand and was just remembering the order of the cars."

ST2: "[Molly] found counting difficult and would refuse to count things, she was a real handful."

ST3: "[Bill] was learning to count to four when we started [the study]. If I counted cotton reels with him and said 'Ok [Bill] where is the number [digit] four?' he would give me the four symbol. He wasn't counting but he did know what the four symbol looked like."

ST3: "[Bill] is very social but does not try to talk. Before we started working with you, [Bill] would count toys and people with my help; if I asked him, but I don't think he really understood the concept of quantity…he is counting now and really seems to enjoy it."

ST4: "I don't think that [Tim] understands counting, even now. He was very hard to motivate and hated counting."

Discussion point 2 – children's progress during the study

The teachers were asked how communication, numeracy skills and behaviour had changed over the study. The following themes emerged from the data:

Table 6.13: Themes relating to children's progress during the study

Theme number	Theme description
6.8	Children spoke during the study
6.9	Motivation to use CAPE V2 increased by making children laugh
6.10	Symbol-scanning skills improved

Theme 6.8 – Children spoke during the study

The support teachers observed that two of the children began to express new words during and after the study. Molly began to say "mookie" and Hugh began to use delayed echolalia. This early development of speech represents an important change in Molly and Hugh's communication development.

ST2: "It was all the other things that came up out of it that were just so wonderful because there were so many spin offs like the communication, the way the lady spoke, I think her voice really helped [Hugh] to learn to listen to instructions and [Hugh] started to talk; yes, it was 'echolalic'. But it allowed people to hear him speak when he hadn't been speaking before."

ST2: "Super Monkey was one of the first things I heard him [Hugh] say properly although it wasn't distinct, it wasn't as clear as I might say it but it was absolutely "Super Monkey". He will not obviously say it if you say "Say Super Monkey" but he did it after this [the study] and he also said "Tidy up" and it was as clear as anything…and he has said it once or twice outside when he has been babbling

and suddenly it just came out. That was huge, something I have not really thought about but it was a good thing. There was just so much, it reinforced the PECS and it allowed us to move the PECS on, actually."

ST3: "[Molly] only used to say "yes" and "no" and most of the time it was no! [Laugh] yes, she was a bit of a madam…but now she is trying to say Monkey! I couldn't believe it when [ST5] told me she was saying I think it was "mookie", you know… when she sees the monkey."

Theme 6.9 - Motivation to use CAPE V2 was increased by making children laugh

Teachers felt that visual rewards that entertained and made children laugh helped to motivate them to use CAPE V2. Super Monkey was seen as being particularly motivating for this group of children. When the children were being entertained by Super Monkey, they were more focused on the work with CAPE V2. The teachers expressed the following views:

ST1 "[Jack] likes being challenged by the game [CAPE V2] and he really likes the pictures and colours…Oh and loves the comic Monkey clips, it really makes him laugh."

ST2: "[Hugh] always likes watching Super Monkey. When you put new tasks on, he would squeal with delight, wouldn't he?"

ST2: "I have been working with [Molly] since [ST5] left and she really loves Super Monkey. When he comes on the computer screen, she starts to smile and laugh. It really keeps her focused on the work."

Theme 6.10 – symbol-scanning skills improved

Teachers noted that children have learned to scan the symbols on their PECS folder before making a request when using CAPE V2 and during PECS lessons. It was suggested that they did not often do this prior to the study, except when they wanted to ask for very motivating things like a favourite food or drink using their PECS symbols.

ST4: "[Tim] didn't really look at the symbols at the start but once it clicked he was away. He looks at the symbols all the time now when he makes a choice."

ST2: "Yes, [Hugh] looks at his symbols more now. He is still a bit forgetful and sometimes he reacts so quickly to a Super Monkey task that I am not sure if he looked, but he definitely looks more than he did."

ST2: "She [Molly] really looks at her symbols. I am not sure if she did before, She seemed to do it in the videos I have seen of her working with [ST5] so I am not sure if this behaviour has changed."

ST3: "Well, I think that he [Bill] didn't look at the symbols before. He just seemed to pick the first one he saw, but now he looks at the symbols before he chooses one."

Discussion point 3 – experience of using CAPE V2 after the study

Five weeks after the study completed the support teachers were asked to discuss the children's use of CAPE V2 after the study. The following emergent themes were expressed:

Table 6.14: Themes relating to CAPE V2 use after the study

Theme number	Theme description
6.11	The children liked using CAPE V2
6.12	Children are still able to use CAPE V2 after two week break
6.13	Individuals' behaviour has changed

Theme 6.11 - The children liked using CAPE V2

Teachers reported that the children liked using CAPE V2. Three of the children used the computer symbol to ask if they could use CAPE V2. Initiating a request for an object was limited to food prior to the study, so this represents a positive change in their communication. Teachers stated that:

ST1: "[Jack] hasn't really changed since you left. He's still very keen to use it [CAPE V2], and when you stopped coming [Jack] would go and get the computer symbol to ask to use it."

ST2: "I would say that all of them were quite keen, even [Tim] who was less keen coming in because I think he knew it was work and he's never been very keen on work. But even he would concentrate on the good days much longer than he would on other work."

ST3: "When you weren't here … and I know that someone else has said this to you…I think I said it to you…when you stopped coming, [Bill] kept getting the computer symbol and I said "No, [Researcher] isn't here" but he had to come in and check that you weren't here in the class because you used to appear while they were doing exercise and then they'd go in the cupboard and you were here. So I think sometimes they thought you'd been 'magicked' from somewhere."

Theme 6.12 - Children are still able to use CAPE V2 after two-week break

All five of the children who took part in the study were able to complete tasks in CAPE V2 after a two-week break from school. Teachers observed that in most cases the children were able to interact independently in the first or second viewing of a task and still showed signs of enjoyment when using CAPE V2. Teachers expressed the following views:

ST1: "yes, we have been using it [CAPE V2] for a session or two since the Easter break. [Jack] can still answer all the counting questions and is starting to get a few of the subtraction questions right."

ST2: "Ha, well we meant to use it [CAPE V2] more but what with Easter and other things we haven't used it as much as I would have liked…The break doesn't seem to have made much of a difference though. When the children started using it [CAPE V2] last week they all seemed to pick it up after a couple of tries. I worked with [Hugh] and [Molly] and they loved it. I don't think Molly even made a mistake and [Hugh] was doing OK after a couple of tries, [laugh] well until he started messing with the speakers again anyway."

ST3: "Well we hadn't used the software for a few weeks but when [Bill] used it again…well, it was like he was on the study again [laugh], he really did well and he still laughs when the cars crash!"

ST4: "Um…well I thought he [Tim] would struggle, you know…but after he made a couple of mistakes at the start everything just seemed to click and he just got back into it after only a couple of tries…and you know, he's still using the symbols he used when you were here!"

Theme 6.13 – individuals' behaviour has changed

Support teachers expressed the view that behaviour exhibited by some of the children had changed since they took part in the research though no direct link can be proven by the research. Teachers reported that for some children inappropriate behaviour had reduced and instances of social interaction had increased, with one child beginning to speak. ST2 and ST3 expressed the following:

ST2 "Her [Molly's] behaviour has generally got better since she started the study but I can't say it is just down to the software. She was coming off Ritalin when we started the study and her behaviour was terrible. However, she did get better and I think that may have been down to her feeling a sense of achievement when she started getting things right with the software. I think it helped but it wasn't the only reason for her behaviour now."

ST2: "He [Hugh] is a bit more social now and, as I said, he has started to try and talk. [Laugh] He came over to me and whispered "Ho, you silly Monkey" last week which was a bit of a shock! His mother tells me that [Hugh] has been playing more with his older sister lately. So it could be that he feels more motivated to talk now because he wants to play with her and her friends, but it certainly is progress!"

Discussion point 4 – advantages and disadvantages of using CAPE V2

The support teachers were asked to discuss their views of CAPE V2. Two themes emerged from the data:

Table 6.15: Themes relating to key functionality of CAPE V2

Theme number	Theme description
6.14	The voice used in CAPE V2 helped the children to understand virtual tutor requests
6.15	The teaching format helped children to learn new symbols

Theme 6.14 – The voice used in CAPE V2 helped the children to understand virtual tutor requests

The virtual tutor's voice was considered to help the children understand the virtual tutor's verbal instructions, due to the slow speed and use of short utterances.

ST2: "The voice really worked well because it was slow, so it gave them time to take in what they were being asked to do before they did it."

ST3: "Yes, I think the way the lady spoke was really good because she spoke slowly and the sentences were quite short and easy to understand…the questions were also repeated which helped [Bill] to learn."

Theme 6.15 – The teaching format helped children to learn new symbols

Teachers felt that a CAL-based teaching tool modelled on the PECS pedagogy helped the children to improve symbol communication. They felt that the use of physical symbols to interact with the virtual tutor allowed the children to practice PECS skills they had previously learned in school.

ST2: "I thought it [CAPE V2] was going to work really well, and it did. It was the whole PECS system and it showed that they understood the PECS process and a lot of them were able to transfer to that [CAPE V2] straight away. Some of them took a little longer but I think that maybe they didn't fully understand PECS anyway, so I think it may have worked in reverse for them."

ST1: "Using real symbols instead of touch screen was really unusual. I think that using the symbols worked really well for Jack because he uses PECS all the time."

ST4: "I liked the lesson format… [Tim] was able to practice doing tasks he had done before and he learned new symbols as well."

ST2: "It's an excellent assessment tool. I think it helped us do a lot of assessment of them and that in itself was good…and the assessment, particularly in the beginning [Hugh] knew he was getting it wrong but he did not know how to get it right. She [Molly] did not know how to get it right either and her self-esteem dropped. It was really interesting to see that because that might have taken several weeks to spot normally. But in that scenario they were getting in a state because they couldn't do it and they knew they couldn't do it…and as soon as you made it that bit easier again by changing to pictures they picked it up and they were happy and we were actually able to move them on"

6.4. Discussion

The objective of the main study was to test an improved CAPE system (CAPE V2) designed to teach counting skills to non-verbal children with autism using the PECS pedagogy. Although the children had similar levels of communication ability their learning needs differed greatly. Therefore, a formative experimental approach and a phased testing schedule was adopted to allow the system to be adapted to each child's learning needs.

To assess the efficacy of the CAPE V2 approach the following evidence was considered:

1. Children's ability to learn to respond correctly to symbol tidy requests by the virtual tutor

2. Children's overall improvement in symbol use

3. Children's interest in CAPE content

4. Any improvement in children's counting skills over the study

5. Improvement to children's verbal communication

6. Influences on social interaction and joint attention

This section discusses the results from the main study in view of this evidence.

Learn to respond correctly to symbol tidy requests from the virtual tutor

Results suggest that all of the children were able to respond correctly to symbol tidy requests by the virtual tutor over sessions. For example the children were able to consistently respond correctly to 100% of virtual tutor symbol tidy requests by the end of Session eight and continued to do so for the remainder of the study (see Figure 6.7). This result signifies an improvement in the children's understanding of verbal and visual output considering the children's learning ability and the shortness of their exposure to CAPE V2 (maximum of only sixteen 10 minute sessions per child).

Analysis of individual results suggest that three of the children (Hugh, Bill and Tim) showed: significant improvement in correctly responding to symbol tidy tasks requested verbally by the virtual tutor; a significant decrease in the need for teacher support; and a significant decrease in incorrect symbol tidy responses

over the reporting period (see Tables 6.5, 6.6 and 6.9). Interestingly, Tim showed the most progress when the percentage of correct responses to symbol tidy tasks are considered for each child. Tim was known to find symbol communication difficult to understand and teachers had expressed doubts of Tim showing any improvement over such a short time (he only took part in fifteen sessions). However, Tim was able to achieve a similar success rate (100%) for responding correctly to virtual tutor symbol tidy requests (see table 6.9) by the end of Session 8.

Quantitative correlation results suggest that Jack and Molly's ability to understand and respond correctly to virtual tutor symbol tidy requests did not change over sessions. However, the percentage of symbol tidy responses and qualitative results suggest that Jack and Molly learned to respond correctly to virtual tutor symbol tidy requests early in the study, which continued until the study finished in Session 16. This apparent difference between quantitative correlation and qualitative results may be because Jack and Molly were able to generalise their previous experience with conventional PECS communication with CAPE V2 user input.

Improvement in symbol use

During the study, all of the children increased the number of symbols they used successfully compared to their pre-study IEP. For example Jack extended his knowledge of digits (previously limited to, 2, 3 and 4) to include 5, 6, 7, 8, 9 and 10 and Bill began to correctly use digit symbols 5, 6, 7 and 8 by Session 16.

Tim used very few picture symbols and had no understanding of digit symbols prior to taking part in this study. To address this issue Tim continued to use picture

symbols during the study. Molly and Hugh had difficulty using digit symbols but were able to answer virtual tutor requests correctly using picture symbols.

Picture symbol tasks were limited to one type of object per quantity. For example, three objects were always represented by three apples. This method was used to help the children build their confidence and learn the basics of physical symbol communication in this context. However, in week four (sessions 13 to 16) two children (Hugh and Molly) were introduced to the banana set (see Figure 6.5) to see if they were able to distinguish between 1, 2, 3 and 4 of the same object. The banana set tasks were designed to help the children to learn to recognise and match different numbers of the same object by recognising and matching the pattern made by the placement of the objects on screen and on the picture symbol.

Molly proved to be the most successful at this task, completing Session 16 with only one error (confusion between 3 and 4 bananas). Hugh was less successful until he had seen a number of exposures of the 3 and 4 bananas tasks but he was able to select the correct symbol for each of the four banana symbols by the end of session 16.

Interest in CAPE content

The children's motivation to interact with the virtual tutor and use PECS symbols was important in this research. The Super Monkey reward content proved to be very popular with all five of the children. All five of the children watched the content without becoming distracted by other stimuli (noises from another classroom, the PECS cards or other objects or people in the environment). Four of the children (Hugh, Bill, Tim and Molly) smiled, laughed and pointed to the screen to direct the

support teacher's attention to Super Monkey. Similar findings were also seen with a different group of children in the pilot study; themes from both studies included *Children enjoyed watching Super Monkey content (*Chapter 5, theme 5.2*)*, *Children smile and laugh when Super Monkey content is played* (Chapter 6 theme 6.3) and *Motivation to use CAPE V2 increased by making children laugh* (Chapter 6 theme 6.9*)*. These results suggest that Super Monkey provided an entertaining and useful reward for answering virtual tutor requests correctly and may provide a useful alternative to food or drink as a way of enticing children to use PECS symbol communication.

Counting skills

This research challenged previously held views of some children's understanding of digits and counting. For example, prior to starting the study, four of the five children (Jack, Bill, Hugh and Molly) were considered, by their teachers, to be able to use digit symbols in traditional counting tasks. However, results suggest that only two children (Jack and Bill) were able to understand and use digit symbols and only one child (Jack) was able to count without support from a teacher.

To support Bill's emerging understanding of digits Bill was encouraged to count each object on the screen with the teacher, prior to selecting a symbol. This method enabled Bill to learn a useful counting method and helped to underpin the relationship between the quantity of an object and the digit that represented it based on his knowledge of digit names and associated symbols. Over the study the counting support was slowly faded out and in Session 11 Bill counted objects on screen (five toy cars) without support from his teacher. This was a major achievement for Bill who had often been difficult to motivate and had struggled with the process of counting for a number of years.

The disparity between early findings in the main study and the teachers' view of children's ability seem to be based on two children's ability to remember the order in which tasks were previously presented and to repeat the order of these responses in subsequent sessions. For example, when the symbols were shown to the children in a different order Hugh and Molly would select symbols in the previous session's order, ignoring the symbols they were actually being asked to choose in their current session.

The change in the presentation of symbols resulted in increasing lengths of delay by Hugh and Molly to select symbols and often ended with a refusal to select a symbol at all. This behaviour seems to indicate that in cases where symbols cannot be matched by type, as is the case with digits that represent the quantity rather than the object type, the child was unable to interpret the meaning of the symbol (digit 8 means 8 objects on screen) they needed to use.

Hugh and Molly began the study using digit symbols. However, assessment of their ability to answer virtual tutor counting questions suggested that they lacked a useful counting method and did not understand the relationship between the quantity of an object (e.g. three apples) and the digit used to represent the quantity (i.e. 3). Based on these findings, (in Sessions 5 and 6) Hugh and Molly were introduced to picture symbols as a replacement for digit symbols.

The move to picture symbols saw an improvement in correct symbol selection and a reduction in inappropriate behaviours and refusal to take part in a task. Hugh and Molly responded to virtual tutor requests without hesitancy, smiled and laughed at Super Monkey reward content and initiated social interaction and joint attention with the teacher supporting their sessions.

Improvement to children's verbal communication

Teachers reported an increase in verbal communication. At the beginning of the study only one child (Molly) used speech and this was limited to saying "no" when asked to take part in an activity she did not want to do. However, in Sessions eight to sixteen of the main study two of the children used speech to request video content and to share their experience with the support teacher. For example, Molly started to say "Mookie" (presumably meaning 'Monkey') in later stages of the study.

The use of verbal communication was also seen in children who routinely did not previously use speech. Hugh was heard to say "ho you silly monkey" to a teacher a few weeks after the study finished. The reason for starting an interaction varied from requests for help when they were unsure of an action, to attempts to share an enjoyable experience. Hugh's emerging use of speech prompted a change in his speech therapy support.

The use of verbal communication observed in the main study was also observed in the pilot study resulting in similar themes emerging from the data (Chapter 5 theme 5.8 – Children used verbal communication during the study, Chapter 6 theme 6.4 Children vocalised when Super Monkey content is played and theme 6.8 Children spoke during the study).

Influences on social interaction and joint attention

The CAPE V2 teaching method provided opportunities for children to instigate social interaction with their support teacher. This was made possible by using a three way communication model where children interacted with the virtual tutor (using symbols) and with their support teacher (using verbal and non-verbal

communication). The three way model has also been used in studies like Robins 2006 with similar success but is not typically used in traditional teaching sessions. However, as these results show the three way communication can have a positive influence on social interaction for children who do not routinely seek communication with others, as was the case in this study. For example, during the study, all five children initiated social interaction with their teacher.

Themes associated with social interaction between the children and their support teachers were also identified in the pilot study and the main study (Chapter 5 theme 5.9 - Children wanted reassurance from their teacher and Chapter 6 theme 6.5 - Children initiate social interaction with the support teacher). These results agree with those in the literature that suggest that CAL can help to encourage social interaction between a child and a support person (either a teacher or a researcher) when a three-way-communication model is used (Williams et al., 2002; Blocher & Picard, 2005; Wright et al., 2011).

Increases in social interaction by children working collaboratively with educational technology have also been observed in the past with diverse groups such as children with high functioning autism (see Williams, 2002) and typically developed primary school children (Wegerif et al, 2003).

6.5. Conclusion

Results from this study suggest that numeracy can be taught using technology-based on the principles of the PECS pedagogy. Children who took part in the study were reported to enjoy working with CAPE V2, and quantitative and qualitative results suggest that four of the five children improved their symbol communication and counting skills during the study. Unfortunately, one child

(Jack) did not show any signs of real symbol communication improvement and it was difficult to encourage him to take part in more than a couple of iterations of a task. This may be because he had a short attention span and was easily distracted by things going on outside of the class.

The use of a three way communication model (see Figure 4.2, Chapter 4) in the main study confirmed findings in the pilot suggesting that the presence of a familiar (to the child) teacher in each session allowed all of the children in the pilot and main studies to instigate social communication, if they chose to do so. This model is not typically used in traditional teaching sessions where simple two person communication is practiced. However, results from Robins & Dautenhahn (2006) and this research suggest that three way communication may offer new ways of encouraging non-verbal children with autism to initiate communication.

Results from the research suggest that CAPE V2 is potentially a strong supplementary method to traditional PECS for non-verbal children with autism. These findings are supported by teacher interviews that express the view that CAPE V2 is a useful assessment and a highly motivating teaching tool.

Results from the pilot and main studies form the findings of this research. Possible explanations and explanations of these results and lessons learned during the design and development of the CAPE approach are considered next.

Chapter 7: Discussion and concluding comments

7.1 Introduction

The work detailed in this thesis was stimulated by the researcher's experiences of raising a child with autism and fulfilling the role of ICT specialist governor at an SEN school. In these roles and as a technologist, the researcher found himself querying why there could not be more technological innovation in the area of communication and learning support for young children with autism. Given the reports of the fascination that some children with autism seemed to have with technical devices such as computers, a potential for developing computer assisted learning systems that would motivate and support such children.

To a child with autism uneasy with the uncertainties of human interaction, computerised interactions may seem an attractive alternative, though the motor skills of such children may be a restriction for them when they attempt to interface with the technology in a conventional way.

When children with autism enter the educational system they are often reluctant to take part in new activities or in activities that do not interest them. A successful learning intervention therefore needs to be enjoyable to the child and draw them in as well as address the child's learning needs. The work in designing a CAL system described in this thesis prioritised the elements of enjoyment and user comfort.

Initial discussions involving the researcher and specialist teachers from a Special Educational Needs school and an initial literature review concluded that contemporary but un-adapted technology could be of limited usefulness to non-

verbal children with autism. However, there could be considerable potential for the appropriate and tailored use of technology.

After intensive consideration a CAL system design was proposed, built around the pedagogically established PECS framework. PECS had been used to support communication development and the teaching of a wide range of curricular subjects. By adopting and adapting technology judiciously it may be possible to provide a CAL-PECS experience which could lead to enhancements in engagement and effectiveness.

Prior to this research there were no known computer-based systems that would support a PECS mode of communication in the way envisaged in the proposed research. Additional benefits could also include, perhaps surprisingly, the potential to develop social interaction (Williams et al., 2002; Leopold, 2007; Tartaro & Cassell, 2008).

7.2 Objectives of the research

Given the initial context described in the introduction, the objectives were expressed in terms of two research questions (Chapter 1, Section 1.3) repeated below:

1. Can a Computer Assisted Learning (CAL) system be designed and implemented to support PECS pedagogy for the purpose of improving symbol communication and social interaction in non-verbal children with autism?

2. To what extent could such a system improve the communication and social interaction skills of non-verbal children with autism?

Question 1 concerned system creation whilst Question 2 was concerned with investigating its efficacy as a method of influencing a non-verbal child with autism to engage in social interaction and communication. Although this implies a two stage process, it was necessary to carry out a much more iterative and integrative approach than this suggests in order to minimise the risk that the system would be rejected 'out-of-hand' by children uninterested in engaging with it after a lot of effort had been expended.

7.3 Design and development of the CAPE system

Early stages of the research identified the opportunity to build a CAL system based on the Picture Exchange Communication System process. CAPE was successfully designed and developed using this PECS pedagogical framework, supported by investigative findings from the relevant literature. This section draws together post experience thoughts about the creation process and realisation of the CAPE designs.

Given the limited motor skills of some children affected by autism, it was important to continue to use physical tokens for communication exchange. This was considered to be preferable to the use of a mouse, touch screen or other input device that may be used by people not having such motor limitations. The exchange though would be primarily between the child and a virtual tutor incorporated in the CAL system, rather than the human teacher in a conventional educational setting (or potentially, in the longer term, guardian in a home setting). This vision led to design concerns that included how selected tokens would be sensed by the CAL system and how a virtual tutor would be designed to provide the lead and feedback to tasks required of the children.

RFID-based technology was adopted to signal the selected token to the CAL system. The advantages of the chosen implementation of RFID technology included being passive (rather than each token needing an individual power supply), meeting important safety requirements and being robust, (surviving for example, being chewed by one study participant).

A first prototype version in the form of the CAPE Simulator was created and its functionality demonstrated and acceptability tested with the assistance of a high functioning child with autism. Such testing provided 'pointers' to features of the system that were likely to be important to a child more severely affected by autism and led to increased confidence in how to design and implement the CAPE V1 and later, V2 systems. For example, this testing highlighted the ease with which a child with autism could learn to use symbols to communicate with an onscreen virtual tutor.

CAPE V1 was designed and created to conduct the pilot study phase of this research. In typical human to human verbal communication the intended interpretation is normally supported by for example, changes of pitch, tone, body language and facial expression. These aspects together convey the intended emotional context (for example, irony, sadness, anger or happiness) of the communication (Nazeer, 2006; Black 2005 in Newman 2005). In all the design work a major aim was to minimise emotional content in verbal output and facial expressions by the virtual tutor that might confuse or distract the children in respect of the tasks presented to them. For this purpose a virtual tutor with limited facial expressions and a voice having limited variations in pitch and tone was devised. The literature had conflicting advice on whether such a virtual tutor

should be designed to communicate with a human voice or whether a synthetic voice would be generally preferable.

The pilot study was used to investigate whether the CAPE design was likely to be practical and acceptable to the target audience. In relation to the voice type preferences, results from the pilot study indicated that for the group of eight children participating in the pilot study the preferred voice type overall was the synthetic voice rather than a comparable natural human voice. This was based upon the outcomes of the measurements which included 'task reaction time' (with and without visual prompt being present) and the child's ability to select the correct symbol for a given task and the time that a child was focused on the CAPE environment and engaging in social interaction with the support teacher. These results suggested that synthetic voice would be more acceptable as the voice of the virtual tutor in CAPE V2 when used with young non-verbal children with autism. However, when comparing these results and those reported in the literature (Williams, 2004; Ramdoss, 2013) it is clear that preferences in voice type may not be universal for all people with autism and preference is more likely to be influenced by the individual's level of communication and cognitive impairment.

The pilot study activities were centred upon a straightforward task and process. Participants were asked to select a food or drink item for Super Monkey. This was followed by a symbol 'tidy' task where participants were asked to return their selected food or drink symbol back to the symbol folder so the task could be repeated or the process finished by their choice. In the case of selecting to continue, the participant would repeat the selection process, but not necessarily for the same item of food or drink. The process of food or drink selection was repetitious but in general the children participating in the pilot study were keen to

continue for several iterations of the process before indicating their preference to finish the process. The method of finishing a session using 'Yes' and 'No' symbols did cause confusion for some children. Although the support teachers felt that teaching Yes and No had some merit for future teaching sessions, it would probably have been better to use the 'finish' symbol to end session considering the limited exposure the children had to CAPE V1 (two ten minute sessions).

The repeated exposure to learning tasks has been identified in the literature as a successful way for children with autism to learn (Michaud et al., 2003, Moore et al, 2005) even though it may not be encouraged for use with typical children. However there is a balance to be struck between some children's desires to repeat tasks indefinitely (a known characteristic of behaviour in children with autism) and the repetition of tasks to establish and consolidate learning. This was a judgement that was made by the support teacher rather than the CAL programme (in both CAPE V1 and V2).

The process that was introduced to the children involved in the pilot study served to test whether the children could engage meaningfully with an alternative PECS-based process whilst also establishing aspects of system design that could be carried forward to the CAPE V2 embodiment.

Overall, the pilot study confirmed that the participating children were able to learn how to interact with a PECS system led by a virtual tutor and using a physical symbol-based communication input. The software designed during this research (known as RFID Bridge) provided a very effective way of supporting the physical interactions associated with PECS within the CAL environment. This conclusion is based upon the findings that all the children in the pilot study engaged

appropriately with the system, in line with their previous experiences and levels of attainment in using standard PECS.

Based on the experiences gained using CAPE V1 in the pilot study, the CAPE system design was subsequently reviewed and further developed into its V2 form. For the main study phase of the research which would make use of CAPE V2, it was decided, in consultation with the school to develop CAPE V2 in the form of a teaching and communication tool. This was necessary for the CAPE V2 approach to be assessed in the context of delivering a portion of the planned curriculum for the main study participants.

A key feature built into the CAPE environments was the use of animations for both the virtual tutor and Super Monkey and verbal instruction from the virtual tutor. Such animations were considered critical from the viewpoints of motivation and continuing engagement.

There were a number of technical deficiencies in CAPE V1 that needed solving before the required performance of CAPE V2 could be achieved. A major constraint in CAPE V1 was posed by the CSLU toolkit system which was unable to provide full body animation of the virtual tutor and with a restricted form of lip synchronisation accompanying uttered instructions, with an additional tendency to crash during operation. It was decided to develop CAPE V2 using Microsoft Visual Basic 6 (VB6). This proved to be a good choice as it provided a flexible and adaptable application programming tool, able to support a wide range of third party hardware and software, including for example, the RFID reader.

Even so, VB6 did not provide a full solution to all problems as it could not provide for instance, the required lip synchronisation with oral instructions of the virtual tutor. The additional use of 'Smith Micro Anime 6 Debut' to synchronise the

avatars' body and facial movements (the virtual tutor) was necessary. Initially the lip synchronisation service provided by the application was inaccurate, but it was possible to edit the 'lip sync textual movement log' to provide an improved voice to face synchronisation accuracy when compared with the CSLU toolkit. Overall these technical 'fixes' provided the means to demonstrate in a one off implementation a sufficiently functional implementation of the CAPE concept in the form of CAPE V2. It is likely that if such a system was to be replicated for use on a national scale that many of the shortcomings overcome by such 'fixes' would be designed out during a dedicated system design process.

Conventional PECS reward systems may be centred on physical rewards such as snacks or access to favourite toys, especially for younger children. However the CAPE approach of using Super Monkey animations and crowd 'cheering' to feedback 'well done' were found to be strong and effective motivators that encouraged continuing engagement and progress, eliciting smiles from the participating children with one exception - when they were rewarded in this way. For this child (the exception) the main focus of interest was on completing the challenges given to him by virtual tutor. Once he had successfully answered the questions he would quickly lose interest and become restless. This suggests that he required a greater number of new experiences to remain focused on the CAPE V2 content.

One disadvantage of the close mirroring of CAPE on PECS in the use of physical tokens was that this placed practical constraint on the expandability of CAPE. For each symbol an RFID chip needed to be assigned appropriate video content and registered in the database. This requirement to create and configure new audio/video content for each token could be an issue in any scaled up system on a

one off basis, but could be justified if the system was to be introduced on a large scale. The cost and effort of creating and configuring a large number of individual RFID PECS tokens with associated content could then be spread over a large number of users and for ongoing repeated use.

Children with autism have as diverse personalities and needs as any other children. During the pilot study it became clear that the level of teaching support needed by individuals could vary substantially, as also observed by Michaud et al. (2003). CAPE V2 was therefore designed such that the teaching support provided could be tailored towards each individual's needs. To achieve this CAPE V2's design included a database to log each symbol the child had learned in sessions to date, and list those new ones that would be taught next. CAPE V2 was also designed to offer a selection of different lesson plans that allowed the teacher to choose how many symbols would be learned in each session and the order that they would be presented to the child. This approach proved effective but involved the teacher typing in symbol names in a set format when configuring the session. This caused some inconvenience to teachers but providing simple preconfigured dropdown selections in future implementations of the CAPE environment would help to streamline data input and reduce the introduction of errors when typing in selections.

In conclusion, the CAPE concept was developed through its three versions and all design concerns were overcome in the final version, CAPE V2. Although there was a very real concern that any deviation from the only system that the children had been exposed to previously (conventional PECS) would create specific difficulties or concern amongst the children, this was not found to be the case. The features that were created within CAPE V2 seemed to be highly motivating to the

children. CAPE V2 was also considered to be useful to the teachers as judged from researcher observations of participant activities and teacher interviews. Future and continued use of the system would benefit from a teachers' manual to ensure that the system could be configured as required, removing the need for specialist knowledge of the system.

In conclusion, CAPE V2 as a CAL system for developing communication skills and learning in a school environment largely met the designer's objectives in terms of attracting and retaining the engagement of the target groups of children and providing a functionality that was appropriate to developing the learning individualised to each child's needs.

7.4 Application of the CAPE system

This section provides a summary review of how the CAPE systems were used in the pilot and main studies, the findings that resulted and thoughts for a continuation of work in this area. The two CAPE systems, CAPE V1 and V2, supported the pilot and main studies respectively.

Pilot study

The pilot study was planned to bridge the gap between the vision of the application of an achievable CAPE system, within the limits of a PhD programme of study, and a basic prototype stage that used the basic CAPE Simulator. In this way the pilot study split the risk that a 'grand design' would be rejected by the target group because it was unsuitable, unattractive or perhaps even threatening in some way. The pilot study provided a proof of concept stage upon which to build plans for the final design. An alternative strategy would have been to attempt to build the CAPE

V2 in a single stage, but without user testing it would have been difficult to anticipate all those aspects that were later found to be important.

Another important aspect of the adopted two stage study (three stages of CAPE development) approach was that it helped to build the interest and support from the teachers over the development period of 3 years. Without teacher support the trials within a genuine classroom context would not have been possible.

Given the rationale for a pilot study, it was decided to design the study so that it produced some useful design input. One of the areas that was highlighted during the literature review was the question of voice type to be used to encourage 'connection' between the target groups and CAPE.

Results from pilot study measurements suggested that when the virtual tutor was equipped with a synthetic voice there were improvements in some of the recorded metrics as compared with when equipped with a natural voice (see Chapter 5, Section 5.4). For example, the children's response times to virtual tutor requests tended to be shorter and more symbols were selected correctly. From this it was concluded that the synthetic voice may be an advantageous design choice for children on the pilot study and possibly to others at a comparable state of development. But as noted previously, children may experience changing levels of preference or discomfort as they progress through various stages of development, such that a synthetic voice could at some stage cease to be a positive comfort, alternatively being perceived as possibly too synthetic (Williams et al., 2004).

Results from the pilot study also served to show that most of the children were able to respond correctly to some virtual tutor requests after only two short sessions, and significant positive engagement was clearly achieved with evidence

of enjoyment, smiling and laughing during use. This was particularly evident when Super Monkey 'reward' content was presented.

In the pilot study some children also initiated social interaction with the support teacher especially when Super Monkey content was shown, responding to Super Monkey's waving (hello and good bye) by waving back at the screen. This apparent need to share such moments with the support teacher was largely unexpected, given that children with autism find social communication difficult and are not normally motivated to initiate or engage in communication with others (Scott-Van Zeeland et al., 2010). However in the pilot study there did not appear to be any correlation between voice type and the instances when social interaction was initiated by the children (either to share the experience or to seek support or affirmation for any action).

Given the target group selection criteria, (Chapter 5, Section 5.3, non-verbal, low functioning) these results were very encouraging. Overall the pilot study results showed that such children with autism can engage positively with PECS in a CAL environment, as offered by CAPE V1. The experiences of conducting the pilot study for both the researcher and teachers provided a level of confidence to proceed further with the design, development and implementation of CAPE V2 for use in a curriculum learning context.

Main study

The main study aims differed to those of the pilot study, being directed towards the delivery of a portion of the curriculum which had been discussed and agreed with the children's school. As such, CAPE V2 was equipped to support the teaching of numeracy, individualised to match each child's Individual Education Plan (IEP). Such individualisation was considered essential by Michaud et al. (2003). CAPE

V2 had been developed to accommodate this requirement, and in doing so reflected the normal approaches used in conventional PECS. In preparation for a session the CAPE V2 was configured with new learning objectives for each child, based upon their previous session results. In PECS alternative symbol types can be selected to represent the same object (for instance, cards depicting food, physical representations of food like biscuits that are covered with resin, food wrappers, and graphic symbols or in some cases photographs (Bondy & Frost, 1994, pp. 79). CAPE V2 utilised picture and digit symbols during the main study, however CAPE V2 use of RFID technology also allowed other symbol types to be used simply by attaching a token to the desired object and associating the RFID token ID with the correct CAPE content.

As the main study progressed teachers reported that they had noticed a reduction in inappropriate behaviour, increases in social interactions and the initiation of spontaneous commenting by children both during and after the study sessions (see Chapter 6, Section 6.3). These results concur with similar findings in the literature (Panyan, 1984; Williams et al, 2002; Massaro & Bosseler, 2003; Whalen et al, 2006).

Again, as was also noted in the pilot study results, it appears that CAPE helped to provide opportunities for child-teacher social interaction and joint attention to take place, that perhaps were different to those presented in conventional PECS usage. Initially this need to interact with the human teacher was usually in the context of a request for help to complete a task. However, later as children became more familiar with the CAPE environment, it became evident that social interaction was increasingly likely to be initiated by the child when they experienced new content or wanted to share their achievement with the teacher.

This increased social interaction also seemed to spill out into some of the children's use of language after the study sessions. Considering that the children selected for participation in the programme were classified as 'non-verbal' it was with great surprise that instances of significant utterances such as "Mookie" (presumably 'monkey') was made by the most severely challenged child, whilst another child began using phrases in an echolalic manner (where there had been nothing before). Shortly after the study had finished another child was heard to exclaim "Ho, you silly Monkey!" This was a phrase used by the virtual tutor in CAPE V2 subsequent to a reward content clip featuring Super Monkey. The child's quite dramatic change in verbal output was subsequently built upon by the provision of speech therapy sessions using language specialists to develop his spoken language skills further (outside this research). Refer to Chapter 6, Section 6.4 for further details.

Overall, the CAPE V2 approach proved to be very successful, if not a little disruptive in terms of challenging some of the pre-existing assumptions about the potential and prior skills of some of the child participants. For example, during the main study phase it was concluded that three of the five participants were able to demonstrate improved symbol use which included a significant increase in the number of correctly selected symbols over this period, as well as changes in motivation, confidence and, in some cases, oral skills.

To conclude, based upon both the pilot and main studies the researcher feels confident in concluding that the CAL version of PECS as realised in the CAPE V1 and V2 versions provided an effective alternative approach to conventional PECs for the groups of children involved in each of the two studies. Although other groups of children may have different needs it appears that there is considerable

potential to develop the systems presented here to a much wider group of users to meet the challenges referred to in Sections 7.1 and 7.2 of this chapter.

The following sections continue to review the research approaches adopted and whether any different strategies may, in retrospect, have been advisable.

7.5 Review of research approaches

Constraints

The main constraints in determining the research approaches adopted were those relating to the number and individuality of the child participants, the nature of their disability and the need to ensure the safety and comfort of children participating in the project. The groups of children selected for this research were diagnosed as having autism, were 'non-verbal' and required significant levels of special needs support.

In view of the nature of autism and the need to conduct teaching sessions carefully and sensitively on an individual basis, the number of child participants was of necessity limited to several rather than many. There were also constraints in terms of the number of available children in one location meeting the studies' specific needs and also the researcher's resources in time and equipment.

The limited numbers of participants was a strong influence on the methods that could be used for data collection and subsequent analysis in both the pilot and main studies. If it had been possible to arrange much larger study populations then parametric statistical approaches may have been possible. But the limitations in numbers prescribed approaches that made use of non-parametric techniques. These allowed the researcher to specify the significance of results in supporting

hypotheses that were obtained from measurements from the small number of study participants.

Whilst it may be tempting to propose that larger scale studies should be conducted using the CAPE environment, such studies would still need considerable resources to be invested. A gradual roll out using localised trialling of the system in similar schools is a more realistic suggestion to gain a wider experience base, involving a wider selection of children, but at a fraction of the cost.

The research was negotiated with the host school so that the study sessions were coordinated into the then current teaching schedule. The main study also needed to tailor the support to individuals. These factors were necessary constraints but had considerable influence on the research and how it could be conducted.

It was also important to put in place appropriate safeguards to protect the children from harm and ensure their rights were protected. This research was defined and administered in line with approved guidance from British Psychological Society and guidelines and subject to ethical approval from the Open University Human Participants and Materials Ethics Committee (see Chapter 3, Section 3.6).

Although these guidelines were addressed to the guardians / parents of the children, the 'in-class' application of the principles was the accepted responsibility of the support teachers. This was a continuation of their normal practice outside the context of the research programme. During the research programme period there were no instances of concern, which required any action under these guidelines.

To develop the research methodology, it was necessary to choose a combination of both quantitative and qualitative approaches (see Chapter 3, Section 3.5). It has been argued that adoption of a pluralistic research approach has particular benefits when attempting to understand real world practice-oriented learning events (Price and Kirkwood, 2014, p. 3). The rationale in this study was that, whilst numerical analysis of children's progress in relation to learning objectives was essential in assessing their achievements with CAPE, this alone might not provide possible explanatory insights into factors that influence how and why the children responded to it.

In practical terms this mixed methods approach was very time consuming, requiring many iterations of analysis to be carried out before a satisfactory understanding of the data was achieved (see a description of the process in Chapter 3, Section 3.5). However, this approach did provide detailed insights into children's ability and motivation to use CAPE and the reasons for their success, or lack of it, over time. These insights (discussed in Chapter 5, Section 5.5 and Chapter 6, Section 6.4) could not have been obtained by the use of a single method. The mixed methods approach enabled a detailed understanding of the ways in which CAPE helped some children to improve their verbal, nonverbal and symbol-based communication, and it helped the researcher to understand why some children did not significantly improve their verbal and non-verbal communication over time.

The use of a variety of methods in the research proved to be beneficial and appears to support the claim by Thurmond (2001) that using a pluralistic methodology "*increases confidence in research data, creating innovative ways of understanding a phenomenon, revealing unique findings, challenging or*

integrating theories, and providing a clearer understanding of the problem"

(Thurmond, 2001, p. 254 cited in Price and Kirkwood, 2014, p.3).

The benefit of using quantitative and qualitative approaches is discussed next, in relation to the pilot and main study.

Pilot study

For the pilot study eight children were available who met the selection criteria. Given this low number, which is typical in research investigations in this context, it was considered important to identify the most productive and robust approach to be used in order to maximise the collection of useful data. Division of the number into two groups of children it could be argued, would provide a controlled comparison, but would have diluted the richness of the resulting data and may limit robust comparisons, especially so because of the variability of the children's initial abilities.

An alternative was to adopt a within-participant's approach, where a participants session results are compared to investigate differences in performance in two research conditions.

Such a within-participants approach is not without its issues however. In the pilot study two effects were of concern. First, if participants were presented with two different conditions within too short a time period the children's performance could be influenced by fatigue with the increasing likelihood of a worsening performance in their second session. Second, there is the possibility that children's performance could be affected by the order in which they experienced the two conditions. For example, if all the children were exposed to condition A followed by condition B

then practice effects could lead to an underlying improvement in performance under condition B given their experiences of condition A.

To mitigate the first concern the two sessions each child experienced were separated by 48 hours, this being a compromise based upon the availability of child participants and teachers within the school schedules. Given a free choice the researcher may have chosen an extended period of separation. However there was no evidence that the delay period chosen was responsible for any distortion of results.

To mitigate the second concern each group of children (with four in each group) were exposed to the two conditions (synthetic or natural voice types) in a different order. Such a within-participant, two condition, counterbalanced design was adopted for the pilot study investigation. In this way each participant's interactions with a given voice type were compared to that of the same participant with the alternative voice type. Quantitative data analysis was carried out using the Wilcoxon signed-ranks test method. Four children experienced the activities with the synthetic voice first and the remaining four children experienced the activities with the natural voice type first. On reflection this seemed to be the optimum choice for this research context, given the constraints that were unavoidable.

It can be argued that significant differences in learning over such short exposures to a new teaching approach could not be reasonably expected (Sheehy, 2009). However, using the approach described, qualitative and quantitative results from the pilot study show that for this population of children when a synthetic voice was used, a significant improvement in the children's ability to interact with the virtual tutor resulted, as compared with the natural voice alternative. These results suggest that voice type should be considered an important feature in

investigations similar to this one, or in wider applications of the CAPE, or similar environments (see Chapter 5, Sections 5.4 and 5.5).

Main study

The main study investigation involved a greater range of observations and measurements in relation to five children engaged in learning activities relating to numeracy. CAPE V2 was used for this purpose. The study involved sixteen teaching sessions for each child, however two children were only able to take part in fifteen sessions over the course of the study. This did not however have a major influence on the results of the children concerned.

During the main study sessions CAPE lessons were individually adapted to the needs of each of the five individuals, gauged from their success in answering the tasks in each session. Each child was also supported over the duration of the study by the human teacher in a manner that was appropriate to each child's needs, and refined as required against progress achieved. Data was collected using several approaches (see Chapter 3, Section 3.2) following a mixed methods approach allied to a formative research approach. Quantitative data was analysed using the Spearman's Rank Order correlation approach and qualitative data by using thematic analysis and critical incident theory. In this way the research questions were addressed from multiple perspectives and with data in both quantitative and qualitative forms to build a deeper understanding than any one method alone could provide.

The selection of a formative experimental approach was based on requirements in the main study. For example, it was important that CAPE V2 could be adapted to support each child's learning needs (see Michaud et al., 2003). Also, the approach had to support a mixed methods approach to allow a more detailed understanding

of the children's use of CAPE V2 compared to quantitative or qualitative approaches alone (Reinking and Bradley, 2008, pp. 34-35). Also the approach had to be focused on the improvement of educational interventions (Reinking & Bradley, 2008, pp. 17-22). It has been argued that action research bears some similarities with the formative experimental approach (see Reason & Bradley, 2001). However, action research has its distinct ethos and ideological goals which the researcher decided could complicate the management of the investigation and could result in reduced researcher control and rigour in the method's application and hence, outcomes.

These issues were considered by the researcher who wished to minimise possible scope creep that could arise should the study aims be subject to joint decisions within a group consisting of teachers and the researcher. The researcher was careful to consider and act upon the teachers' professional advice and close knowledge of each participant. It is acknowledged that in such investigations the researcher may inadvertently or otherwise introduce his or her own bias, but this was minimised in the research approach by ensuring that full consultation with the teachers took place, and basing any modifications to the CAPE features or application to the investigation on their advice.

The whole-hearted commitment demonstrated by the teaching staff at the school indicated that inclusiveness of the opinions and perspectives of teaching staff in setting the direction of the investigation, or participating effectively in it, was not problematic in any way. What would have been a problem was if more time commitment had been requested and that would certainly have been required in an action research approach.

Data from qualitative approaches

In addition to the data collected from the studies using quantitative approaches referred to earlier in this review chapter, qualitative data was also collected from researcher and teacher observations, audio-video recordings and researcher noted records of session activities. After each session teachers were asked to watch the audio-video recording of the session and to comment on the child's observed behaviours. Post-study, semi-structured interviews were another source of qualitative data. The following reviews how these methods contributed to the emerging picture of CAPE's utility.

Semi-structured interviews with teaching staff

Semi-structured interviews were conducted shortly after the pilot and the main study to elicit reflective commentaries from the teachers who had supported the children in session activities. Of particular value was feedback concerning system design and participant activity and performance, given their knowledge of the participants' personalities and learning needs. Teacher interviews and informal consultations also served to include the teachers and acknowledge their contributions to the work. Unfortunately, one of the five teachers moved to another school and was not available to be interviewed in the final semi-structured interviews held with support teachers after the main study had completed. This did not however have a major influence over the findings of the main study because she had made known her general views to the researcher prior to her leaving.

Thematic analysis

Thematic analysis was used extensively during the pilot and main studies to extract meaning from recorded data and observations. Coding and grouping data into categories and themes was time consuming, but it was successful in developing a detailed and rich understanding of session activities (see Chapter 3,

Section 3.4). Two examples were a deeper understanding of a child's use of symbols, and the way that Super Monkey influenced children to continue interacting with CAPE over the main study duration.

The process was applied to video recordings of sessions which were repeatedly scanned for observed participant behaviours and key activity, and was facilitated by the software application, Focus 3. This tool allowed raw video recordings to be analysed and re-analysed and through a process of coding, categorisation and theme development, to identify emergent themes that had not been evident before the process had been undertaken.

A disadvantage of adopting Focus 3 was the need to be repeatedly stop and start the video recording to create new code names before assigning them to the newly identified and coded data. With traditional coding, codes can be created immediately and assigned without breaking the flow of the initial coding pass. This disadvantage of Focus 3 was offset however, by the benefit of being able to repeat specific events within controllable time windows.

The cyclical and iterative processes of thematic analysis had the effect of thoroughly immersing the researcher in the detailed data so that individuals' interactions with CAPE, or comparisons between individuals' interactions with CAPE could be better understood. Focus 3 proved to be very helpful for controlling and analysing audio-video recordings of sessions. If this research was to be conducted again then Focus 3 would be used as a way of controlling video content during the transcription of the session in a word processing package. This package would contain a suitable table for recording codes and later categories associated with the data. Coding would then exclusively take place in the word processor document once transcription has been completed.

Critical incident method

The critical incident method was used to highlight critical changes in behaviour or activity when a child was undertaking a CAPE related activity. Examples included the first time a child looked at the symbols in the folder during symbol selection or the first time a child used verbal communication during a session. Critical incidents were identified using transcripts from the main study derived from the audio-video recordings. The occurrence of critical incidents could on occasion be explained in terms of the thematic analysis results, to which it was complementary. Critical incidents could sometimes be used to identify then explain the factors that influenced the way the children interacted with CAPE.

Critical incident analysis proved to be invaluable in the main study investigation, complementing the outcomes from thematic analysis and facilitating a deeper understanding of the events observed and reasons for changes in the way participants interacted with the CAPE system, their peers and their teachers. Identification of behaviour changing events allowed the researcher to rationalise how elements of CAPE pedagogy could influence specific behavioural change over time in individual children, as compared to the group as a whole. Critical incident analysis was not used in the pilot study because there was a likelihood that significant changes in behaviour would not be observed in such a short study (only two sessions per child).

Potential weaknesses of critical incident analysis identified during its use in this study included firstly, its reliance on the observer's memory with respect to detailed relevant factors and secondly, a focus on events that may not represent behaviour that may be exhibited by non-verbal children with autism. These weaknesses were overcome in the main study by video recording each session

and reviewing each recorded session with teachers to understand key changes in a child's known behaviour.

7.6 Conclusions

This investigation has demonstrated that a Computer Aided Learning system in the form of CAPE can support a PECS pedagogical approach to teach symbol-based communication skills to non-verbal children with autism.

The work carried out resulted in a CAPE design that used a virtual tutor to lead the activities undertaken by the children with the additional support of a human teacher. An RFID tag system signalled the identification of chosen symbols to the CAL system, enabling physical symbols to be retained that would be acceptable and familiar to children using conventional PECS. The design developed over the duration of this investigation was able to support symbol communication and learning in scheduled curriculum tasks. Important design features to promote engagement, enjoyment and motivation included a virtual tutor. Although human-like, the virtual tutor was equipped with an expressionless face and emotionless synthetic voice to 'connect' with the children. Animations featuring Super Monkey provided a fun element and the primary motivating factor. All the child participants successfully engaged with CAPE (depending on their learning ability).

The final version of CAPE achieved in this work included sub-systems that enabled the children's teachers to develop individualised lesson plans and track the performance of the children when using CAPE.

Eight children took part in the pilot study using CAPE V1 and five in the main study using CAPE V2. All were categorised as non-verbal at the start. The pilot study demonstrated that such children could engage successfully with the system and

carry out simple tasks such as choosing food or drink for Super Monkey. The study helped to ascertain the children's preference of the virtual tutor voice type, an electronically sourced synthetic voice.

CAPE V2 provided a more comprehensive and sophisticated system which demonstrated how communication skills (both oral and symbol-based) could be developed successfully in a classroom learning situation. The curriculum subject area for this was numeracy. Whilst all of the children had severe communication problems they were very much individuals and consequently benefited in different ways (as described in Chapter 6, Section 6.4). Some communication development was remarkable in that two out of five children in the main study who started to produce new verbal output (utterances) in the main study, continued to develop new output afterwards. As the numbers of participants was constrained a control group comparison would not have been possible, so such advances cannot be directly attributable to CAPE alone.

Teachers involved in the main study considered that CAPE V2 was a valuable teaching and progress-testing tool, (which the school requested remain in place after the research had completed). The children involved in the main study showed variable degrees of improvement in their numeracy (counting) skills and number recognition. CAPE V2 allowed teachers to monitor the children's interactions and to assess progress by detecting true participant understanding of key numeracy concepts rather than memory-based responses that were not underpinned by understanding. During the main study three of the five children were assessed as having made significant gains in their numeracy and all five learned some new skills and symbols. All the children appeared to enjoy using the CAPE V2 environment and were judged to have increased levels of confidence that they

displayed beyond their numeracy learning. Teachers involved in the main study sessions indicated their enthusiasm for extending the CAPE 'toolkit' to facilitate a wider range of curricula subjects to be supported.

An unexpected effect of the use of CAPE V2 was in the changes in social behaviour observed in several of the children. Given that the virtual tutor provided the teaching instructions, the human support teacher now provided support but not the initial direction to the children. In this changed situation and during use of CAPE V2, four of the five children involved in the main study initiated social interaction in some form with their support teacher. This is an important observation involving children with autism where there is invariably a preference to avoid social interaction. Teachers and the researcher noted that the instances and strength of inappropriate behaviours also reduced markedly during this period (Chapter 6, Section 6.3). These social and behavioural aspects may possibly help reduce the barriers that hinder development of improved learning and communication. Such changes in social connection with the human world can be considered big steps forward in the development of children with autism at this level.

The following paragraphs are concerned with pointing to possible future work that could build upon the current concept of a CAL system such as CAPE V2 to support communication and learning development in children with autism.

CAPE V1 helped to provide proof of concept with specific emphasis on determining the synthetic voice versus natural voice dilemma. There are other design features that could be similarly investigated to help develop an optimum CAPE environment. Character appearance and gender may be significant factors for the virtual tutor. Furthermore it may be useful to consider whether the Super

Monkey character or a non-human-like alternative could be more effective as virtual tutors and leaders of the learning activities.

Whilst CAPE V2 in its present form would not be suitable for home use, further development work could produce a version that children's guardians could use in the home environment. It would need to be designed so that it was suited to use in the presence of a guardian assumed not to be a teaching specialist. A design version could be envisaged that could help, for example, to consolidate school learning activities in the home and this could be particularly beneficial. It is unlikely that a version could or should be produced that children with severe communication difficulties could use alone. Work to investigate these possibilities could help contribute significantly to children's development.

The question of whether a form of the CAPE environment would be suited to supporting the development of pre-school children is another area of potential research, design and development. As indicated previously, an early intervention is likely to be beneficial, but future research would need to be carried out to determine in whether such a system could be beneficial and what its design goals would need to be. Such a system may not be appropriate or helpful for very young children.

The social aspects of CAPE use were largely unexpected in this investigation. Any development in social activity in these children can help forge a 'connectivity' with the world and this in itself is of immense potential value to the children. Future research could focus on how the technology surrounding CAPE could be developed to further foster joint attention and behaviour change.

Some children's development of utterances during the main study sessions was an unexpected and significant outcome, stimulating the question as to whether

speech development could be further stimulated over a longer term in a CAPE like environment. A similar observation and potential exists in terms of developing awareness of expression and emotion in children with autism. Flash cards are used rather than a conventional PECS environment, but a modified CAPE could provide both.

Personal concluding comments

In carrying out this investigation with children who experience a very different world to the one that I am familiar with I have become acutely aware of the barriers that impairments in social interaction and communication can have on children with autism. An adult with Asperger's syndrome quite aptly describes her experiences of living in society is like

> *"sitting behind a frosted glass wall, being able to see the world but unable to get into it."* Buten (2007).

Although this view has been expressed by a verbal adult with Asperger's syndrome it is possible that a similar view of society may be expressed by a non-verbal child with autism if they were able to communicate. From this perspective it is clearly important to address social interaction and communication impairment as soon as possible after a diagnosis of autism is received. I hope that this work will help focus further attention to the issue of how we support such young people to be become fully functioning human beings who can connect with a world that is increasingly complex and potentially confusing for everyone.

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Appendices

Appendix A- Glossary

Abbreviation/ name	Meaning
AAC	Augmented and Alternate Communication
ABA	Applied Behavioural Analysis
ADI-R	Autistic Diagnostic Interview – (review)
ADHD	Attention Deficit Hyperactivity Disorder
AI	Artificial Intelligence
AS	Aspersers Syndrome
ASD	Autism Spectrum Disorder
ASL	American Sign Language
Aspie	Slang term used by autism community for a person with Asperger's Syndrome
ASQ	Affective Social Quotient Project
Autie	Slang term used by autism community for people with autism
BADS	Behavioural Assessment of Dysexecutive Syndrome
Bluetooth	Product name of a wireless technology
Brigadoon	Name of Second Life world dedicated to people with autism
BSL	British Sign Language
CA	Conversation Analysis
CGI	Computer Generated Imagery
CAI	Computer Assisted Interaction
CAL	Computer Assisted Learning
CARS	Childhood Autism Rating Scale
CAT	Computed Axial Tomography
Chatbot	A tool that allows people to communicate using online chat
Circle Time	A teaching method were participants sit in a circle and use verbal/non-verbal communication to discuss issues or talk about their feelings and needs
CRB	Criminal Records Bureau
DISCO	Diagnostic Instrument for Social and Communication Disorders
DSM IV	Diagnostic Statistical Manual (No 4)
DSM V	Diagnostic Statistical Manual (No 5)
Echolalia	To repeat another's utterance either immediately or at a future time
EIBI	Early Intensive Behavioural Intervention
HFA	High Functioning Autism
fMRI	functional Magnetic Resonance Imaging
INSAR	International Society of Autism Research
MAKATON	MAKATON is a trademark name taken from the original creator's first names: MArgaret Walker, KAthy Johnston and TONy Cornforth
MEDIATE	Multisensory Environment Design for an Interface between Autistic And Typical Expressiveness
MRI	Magnetic Resonance Imaging

NAGTY	The National Association of Gifted and Talented Youth
NAS	National Autistic Society
NLD	Non-verbal Learning Disorder
NDD	Neuro Developmental Disorder
PAT	The Play and Tell project
PDD-NOS	Pervasive Developmental Disorder Not Otherwise Stated.
PECS	Picture Exchange Communication System
PET	Positron Emission Tomography
PIQ	Performance Intelligence Quotient
RFID	Radio Frequency Identification
Schome	Not home, not School
Second Life	Online virtual environment
SEN	Special Educational Needs
SGD	Speech Generating Device
TEACCH	Treatment and Education of Autistic and related Communication handicapped Children
TEALEAF	Teacher Embodiment and Learner Affordances Framework
ToM	Theory of Mind
TTS	Text To Speech
VIQ	Verbal Intelligence Quotient
VE	Virtual Environment
VOCA	Voice Output Communication Aid
VR/VRT	Virtual Reality/Virtual Reality Technology

Appendix B – Study parental consent form

Department of Communication and Systems

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Parental Consent for Minors – Letter of Information

Dear parent/guardian,

I am the father of a child who has been affected by autism and who attends <host school name>. I am also a doctoral student at the Open University working with <host school name>.

The research project I am engaged with aims to help improve the way children with autism develop their communication skills using an approach-involving computer-based tuition. In this approach, a virtual tutor (on a computer screen) leads the child through tasks similar to those that a human teacher would normally facilitate.

Broadly, the virtual tutor prompts the child to respond to words and concepts they are learning about by selecting one from several electronic tokens (similar to the PECS tokens your child currently uses, but which can be sensed and monitored by a computer). The child's selection is recorded by the computer and the virtual tutor feeds back to the child to support and consolidate their learning. In the activity, the child will also be supported by their teacher who will be present throughout the planned activities.

My role will be to observe, discreetly, how children interact with the virtual tutor in the presence of their usual teacher, and to collect and record data relating to the responses the child offers. This will include audio and video recording of these activities.

If you agree to your child's participation, they will be involved in four 10-minute computer-based activity sessions per week for each of four weeks. We plan to carry out this study from Monday 17th January to Thursday 10th February 2011.

This letter is to ask you if you are willing to allow your child to participate in these research-related activities. If you agree, please complete the attached letter of consent and return it to <teacher's name> at <host school name>.

Should you wish to be informed of the eventual outcomes of the work, I will provide a synopsis of the progress of the project based upon preliminary, anonymised findings through <host school name> at an appropriate time.

I am also attaching a summary of the precautionary measures to be adopted to ensure the well-being of the children. If you have any questions concerning the arrangements or the research study itself, please contact me, or my research supervisor, at the Open University.

Thank you.

Yours faithfully

Paul Herring (research student)

Email: <researcher's email address>

Mobile: <mobile number>

Research supervisor:

Dr Roger Jones

Email: <Dr Jones email address>

Tel: <OU number>

Mobile: <mobile number>

Please return the completed form to:

<Teacher's name>

<Postal address of school>

Summary of precautions and protocols for the trial

- If you agree to your child's involvement in the study, your child will still be in the company of his or her normal teacher, who will continue to be present at all times during my presence in the school;

- The study will adhere to all school, DfES and British Psychological Society (BPS) regulations including those relating to health and safety, Data protection and child safety;

- During my visits to <host school name>, I will work under the direct supervision of the teaching staff. At no time will I work in an unsupervised one-to-one mode with any pupils at the school;

- Any changes to learning schedules or arrangements will be introduced in a controlled way and in strict accordance with school procedures;

- No new learning aids will be introduced without the prior consent of the school;

- The computer-based sessions will consist of a 10-minute session on each of two days per week, for four weeks. If at any time a pupil exhibits any sign of discomfort, the teaching staff will assess the situation and manage the situation as they would normally do;

- All the data I collect from the study will be treated as strictly confidential and will remain anonymous. Some audio and video recordings will be made during the study sessions. All video and audio recordings will be stored, in a safe and secure place and will then be destroyed when the research has been completed;

- The results of the study, should they be published, will include no names of any child. No video, photographic images or sound recordings will be included in published data;

- Participation in this study is entirely voluntary. If you are not willing for your child to participate in the trials, or if your child does not wish to take part that is fine. If you wish to participate and then change your mind (or your child indicates this) please be assured that we will respect your wishes and withdraw your child from the study.

Letter of consent (parent or guardian)

I have read and retained a copy of the information provided and am happy with the explanation of the purpose of this study.

I understand that the findings of the research study may be published but no names nor recorded material will be published. Recorded material will be destroyed when the research has been completed.

I understand that participation is voluntary and that my child is free to withdraw from the study at any time without negative consequences.

I understand that if I want to discuss any matter related to this project with a person other than the researcher, I can contact Dr Roger Jones, the researcher's supervisor (contact details in the accompanying letter).

I have read and understood this consent form and the information

contained in the accompanying letter and I agree to allow my

Son / daughter whose name

is…………………………………………………… to participate in this study.

I would / would not like to receive feedback from the study at appropriate stages.

Name of parent/guardian: _____

Signature of parent/guardian: _____

Date: _____

Appendix C – child participant observational protocol, CAPE main study

Child participant observational protocol

CAPE main study

Child   **Date**

Session   **Time**
number
Observer   **Supporting**
                                             teacher

(Fill out prior to session observation)

Location of lesson:

Lesson objectives:

Intended outcomes:

(Researcher to fill out following table for each interaction/symbol exchange for each child during session)

Trial No	Appropriate behaviour (Y/N)	Appropriate symbol selected (Y/N)	Symbol chosen	Symbol expected	Notes
1					
2					
3					
4					
5					
6					
7					
8					

Trial No	Appropriate behaviour (Y/N)	Appropriate symbol selected (Y/N)	Symbol chosen	Symbol expected	Notes
9					
10					
11					
12					
13					
14					
15					
16					

(To be completed directly after the child participant session)

Appendix D: CAPE V1 code structure
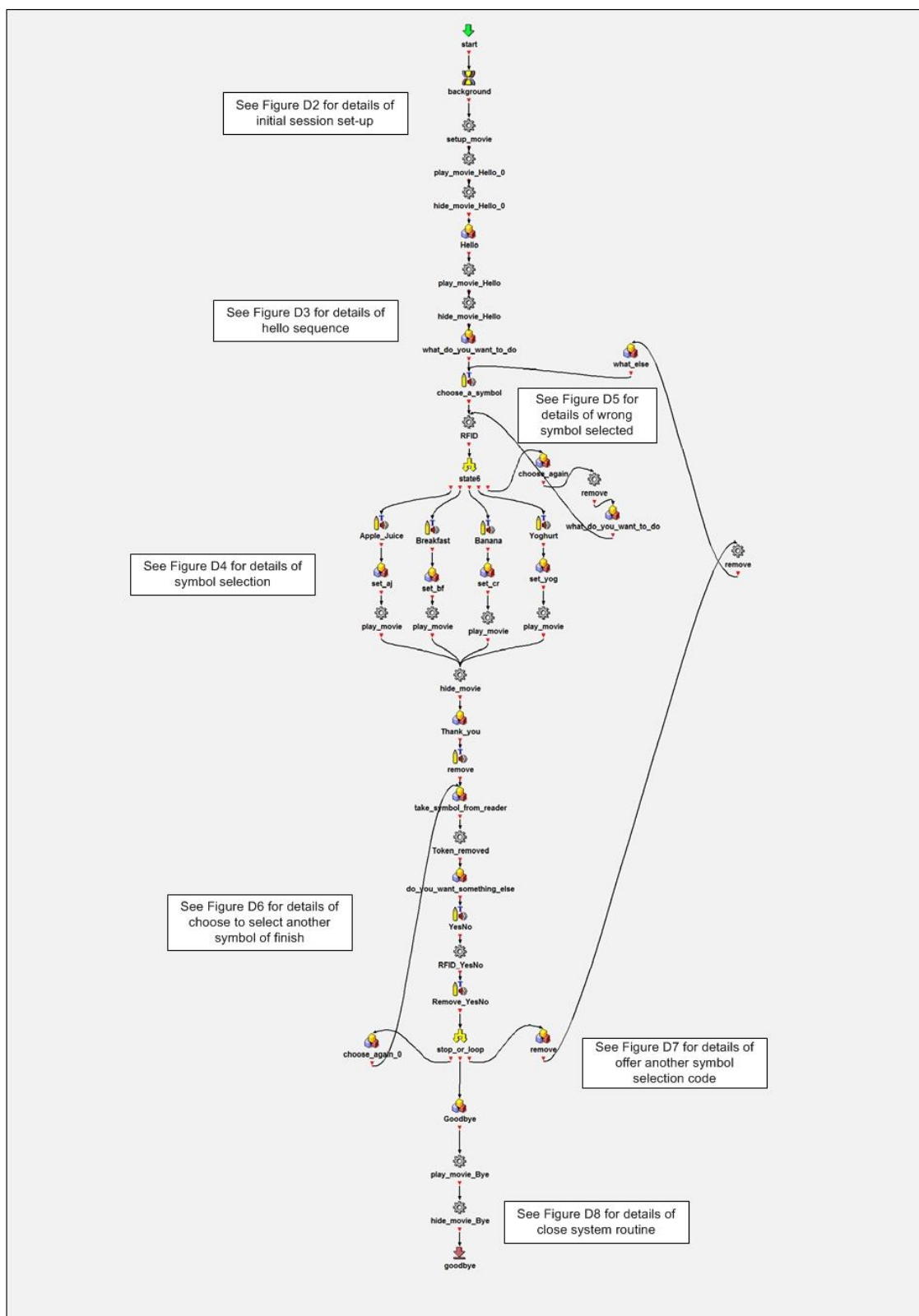
Figure D1: CAPE V1 system structure

```
set colour azure2

set b .background

toplevel $b -bg $colour -height [expr [winfo screenheight .]-28] -width [winfo screenwidth .]
wm overrideredirect $b 1
wm geometry $b +0+0
raise $b
button $b.quit -text "Exit" -command [list destroy $b] -width 12
pack propagate $b 0
pack $b.quit -side bottom -anchor e
bind $b <ButtonPress> [list raise $b .]
```

```
# Load the QuickTimeTcl package
#
if {[catch {package require -exact QuickTimeTcl 2.1} msg]} {
 tk_messageBox -type ok -icon error -title "RAD Movie Example" -message "The QuickTimeTcl package could not be found.
Please copy the \"[file join [pwd] QuickTimeTcl]\" folder
to \"[file join $env(CSLU_PREFIX) pkg QuickTimeTcl]\", then re-run this RAD application."
 tcl stopSystem
}

namespace eval ::QT {
 variable top
 variable mov

 # Create a simple movie playback window.  Withdraw it for the time being.
 set top [toplevel .quicktime]
 set mov $top.movie
 wm withdraw $top
 wm title $top "RAD Movie Playback"

 wm geometry $top +450+400
 update
}

proc ::QT::waitUntilDone {widget {granularity 100}} {
 while {1} {
  if {[$widget isdone]} return
  after $granularity {set ::CheckDone 1}
  vwait ::CheckDone
 }
}

proc ::QT::show {} {
 variable top
 wm deiconify $top
 update
}

proc ::QT::hide {} {
 variable top
 wm withdraw $top
 update idletasks
}

proc ::QT::playFile filename {
 variable top
 variable mov

 if {![file readable $filename]} {error "\"$filename\" cannot be read."}

 show

 if {![winfo exists $mov]} {
    Movie $mov -file $filename
    pack $mov -expand 1 -fill both
 }

 {
  $mov configure -file $filename -width 450 -height 350
 }

 update idletasks
 $mov play
 waitUntilDone $mov
}
```

Figure D2: Initial configuration of CAPE V1
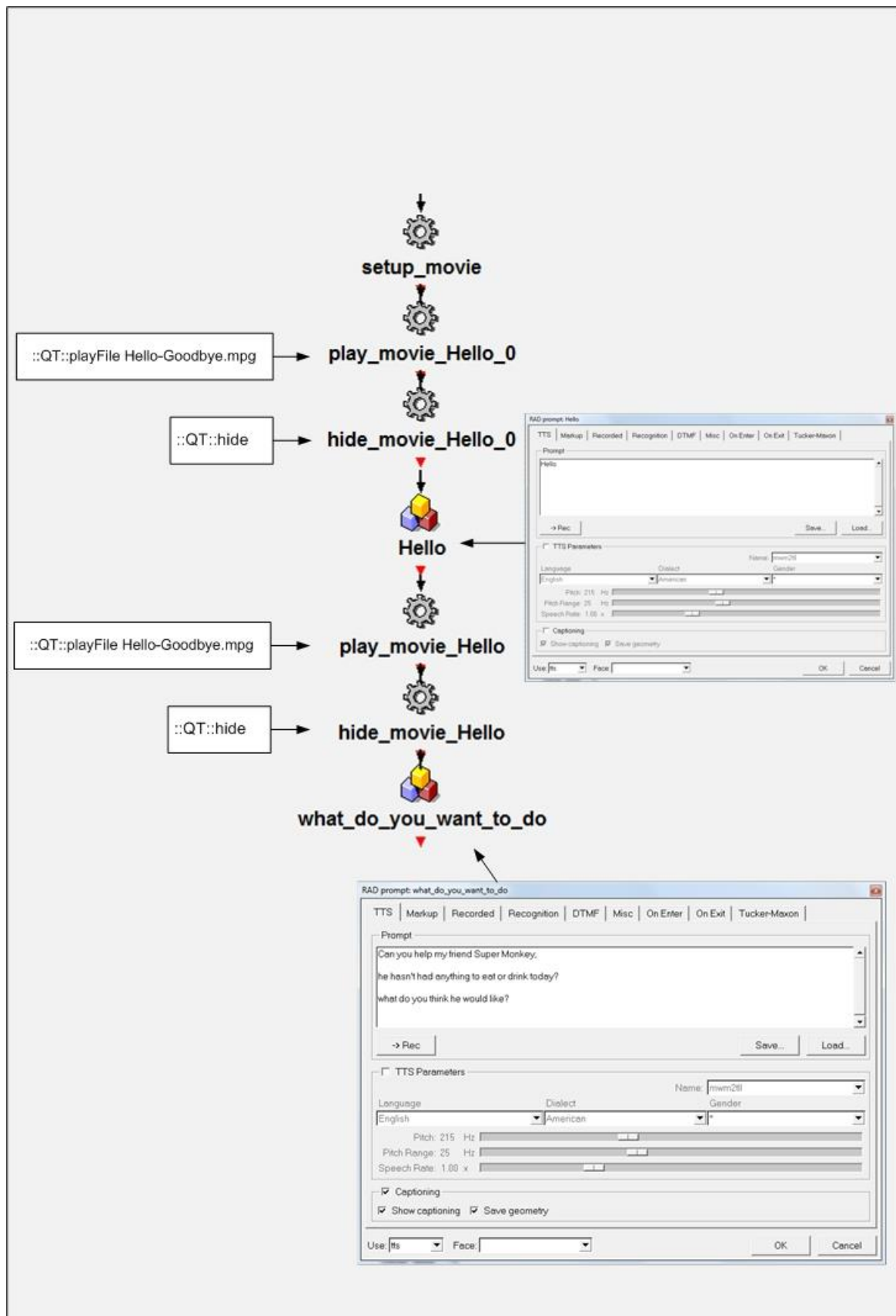
Figure D3: CAPE V1 Hello-goodbye sequence
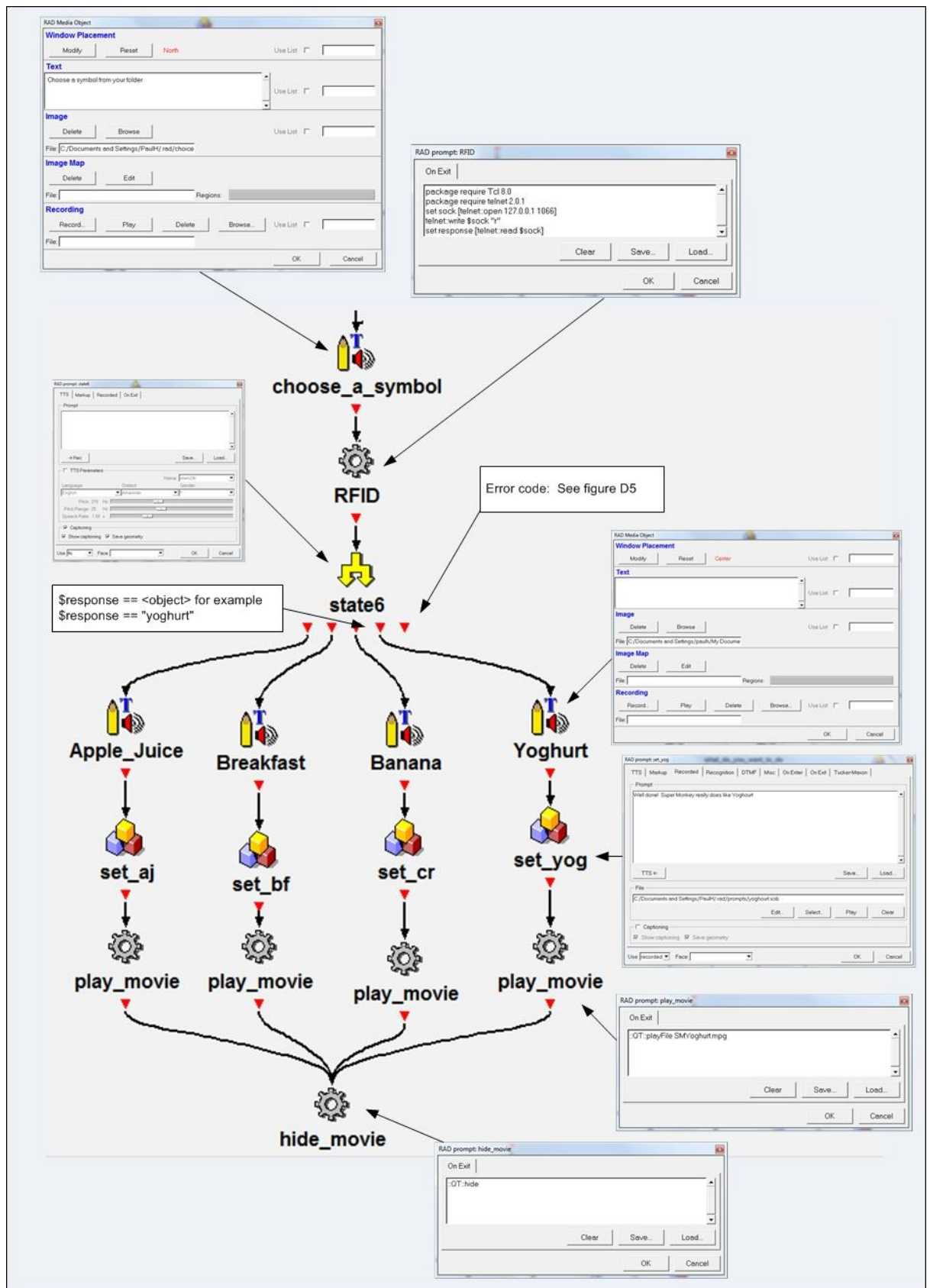
Figure D4: CAPE V1 symbol selection code
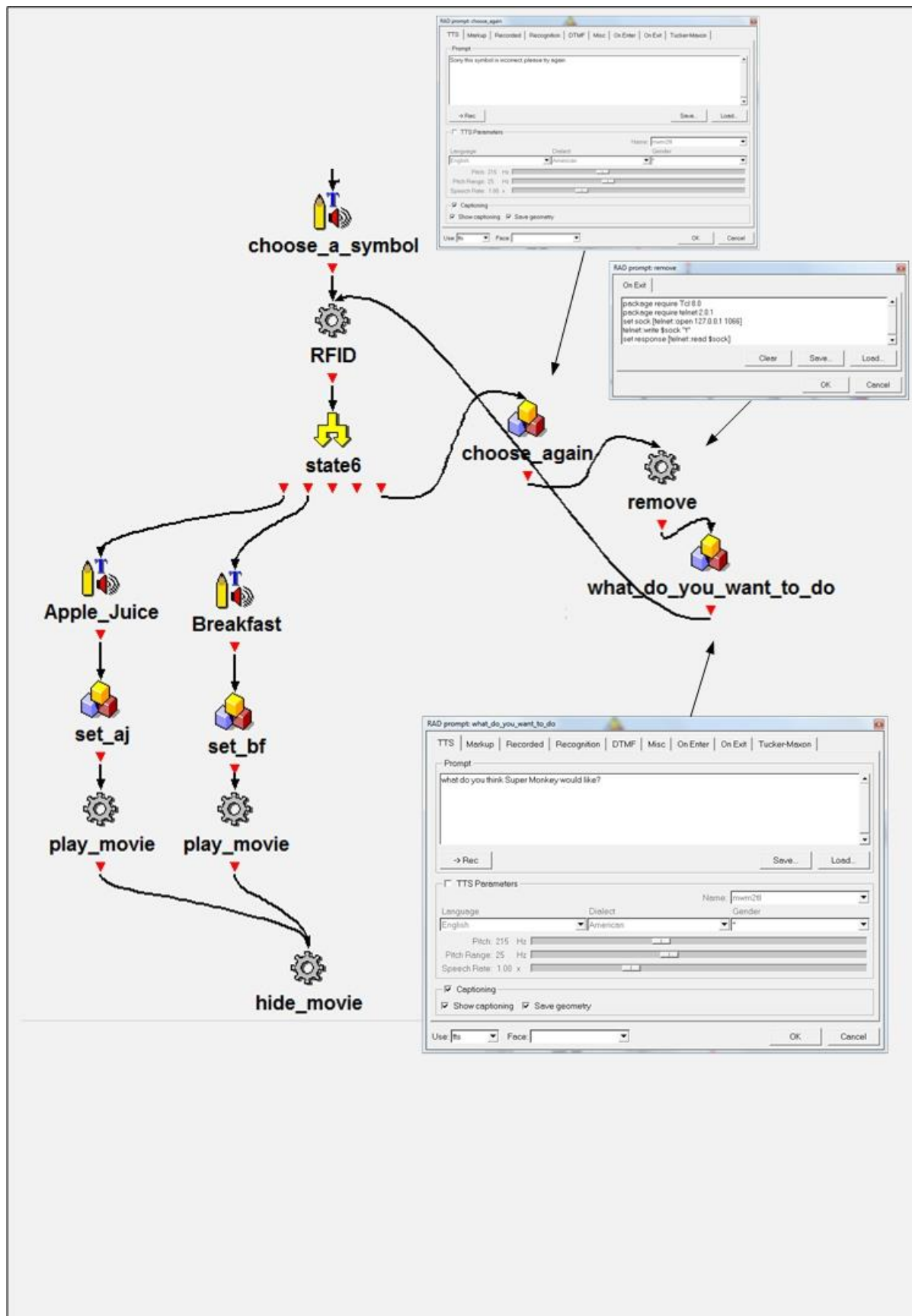
Figure D5: error code for incorrect symbol selection
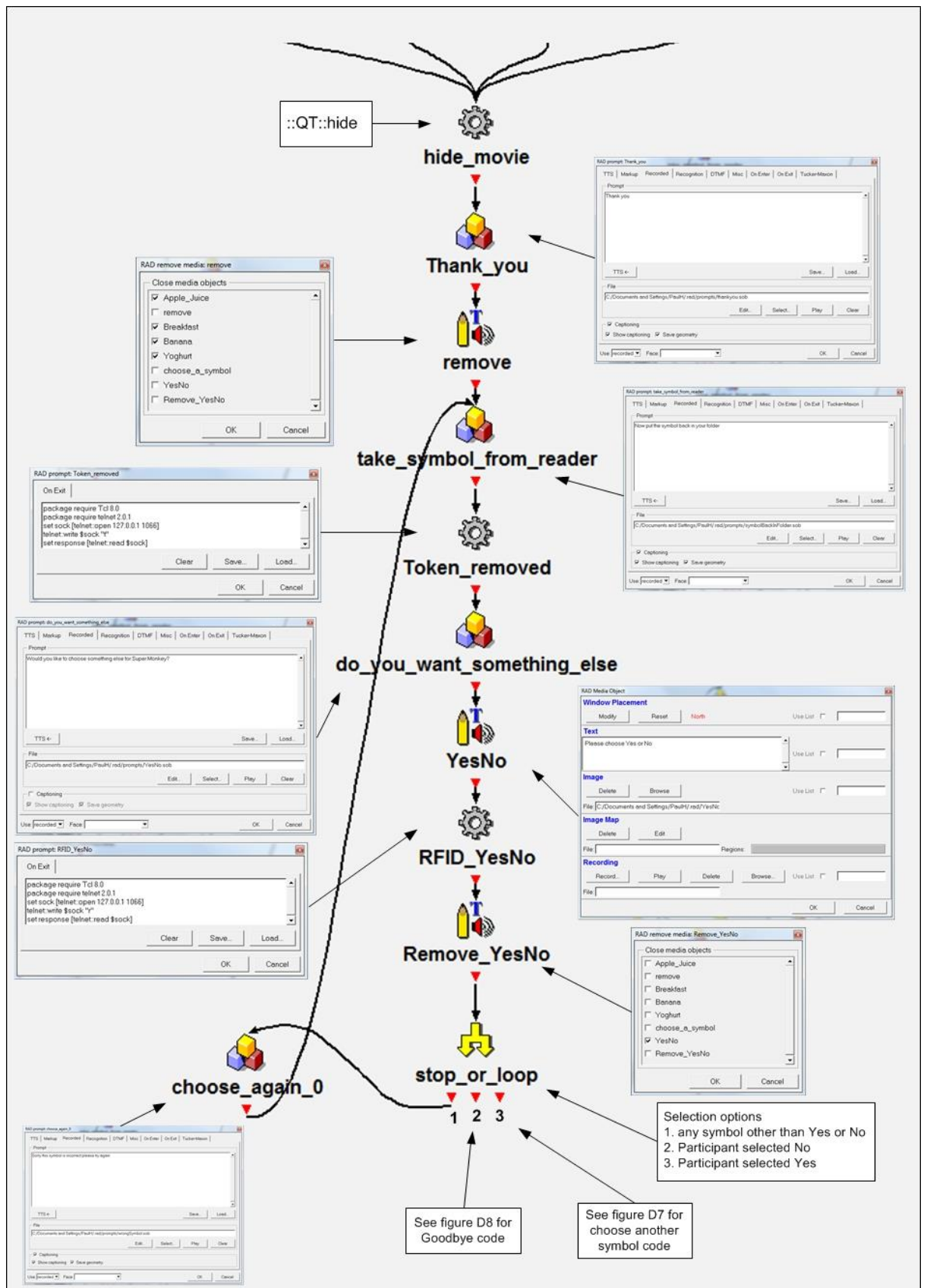
Figure D6: Choose to try again or exit CAPE V1
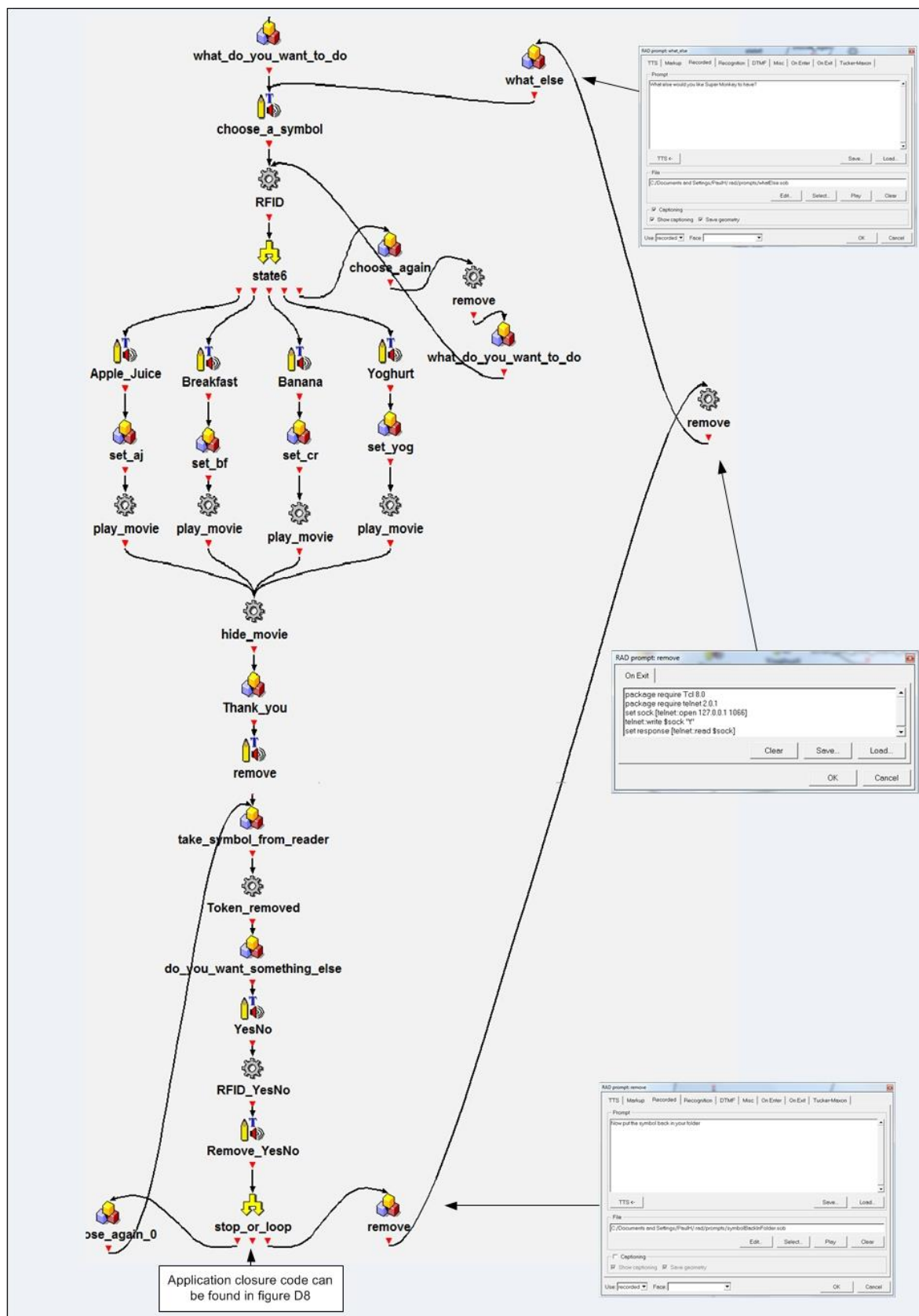
Figure D7: Select another symbol code (CAPE V1)
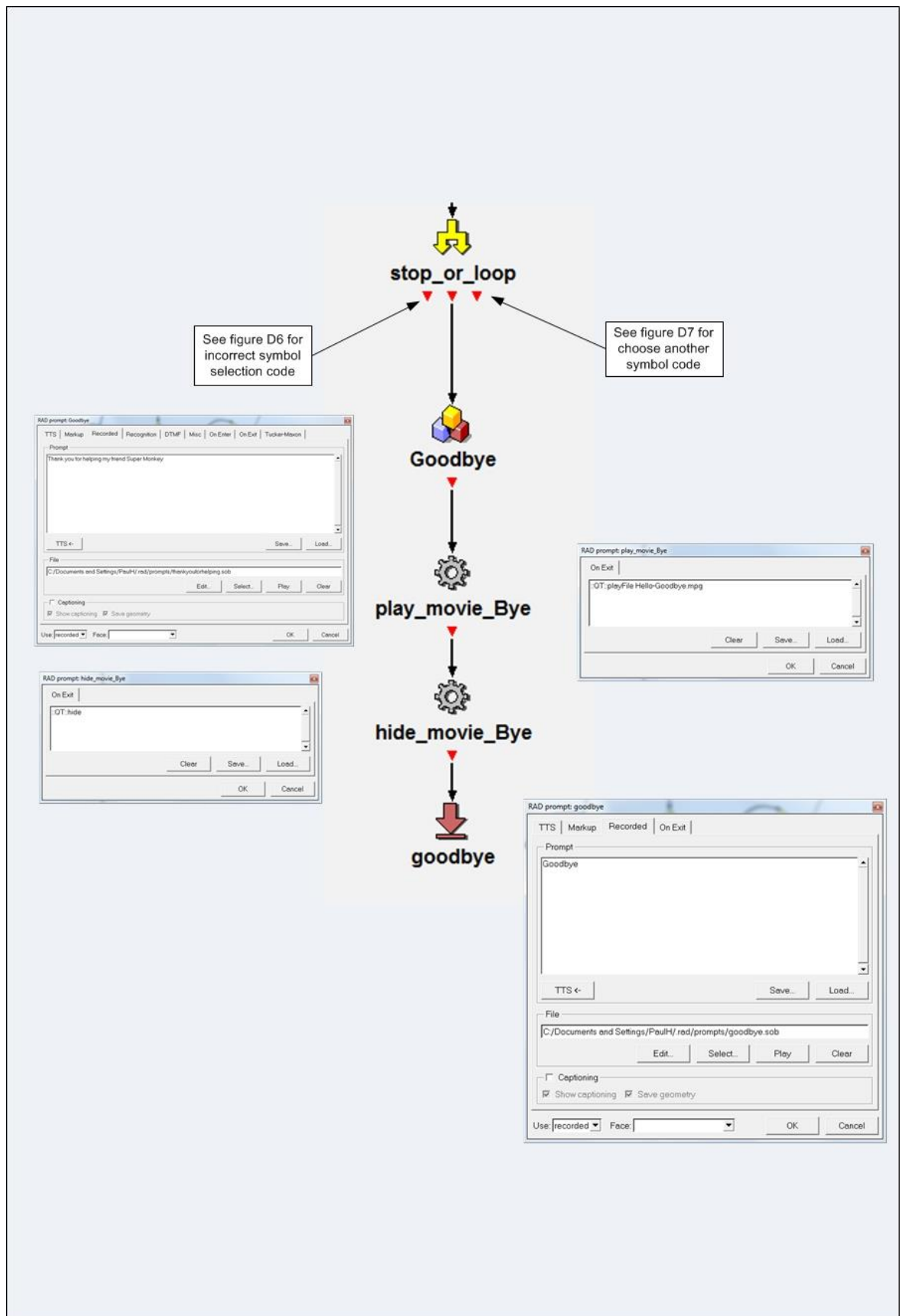
Figure D8: Application closure code

Appendix E: Software programming tools used to develop CAPE

Table E1: Software programming tools used in the development of CAPE

System / sub-system	Software / programming tools employed	Affordance
RFID-Bridge	Microsoft Visual Basic 6 (VB6)	A software-programming tool that allows the programmer to utilise 3rd party API and allows the developer to create Windows-based programs.
	Microsoft Access 2003	Provides a way of searching a data source containing known RFID tag numbers and retrieving the tags allocated symbol, which can then be sent to CAPE as a response to an RFID reader request.
	Chilkat ActiveX VB6 sockets library	A 3rd party API that provides a method of communication between different applications on a network or on the same computer.
CAPE V1 client software components	Tool Command Language (TCL) 8.0	A flexible programming tool that helps to enhance and extend existing application sub-systems provided by the CSLU toolkit.
	Centre for Spoken Language Understanding	A development environment that allows novice and professional developers to build complex applications using object-based programming functions.
	QuickTime TCL dynamic link library	A software tool that provides video output (see figure 4.6)
	TCL Telnet 2.0.1	To send and receive RFID requests from RFID-Bridge on TCP port 1066

System / sub-system	Software / programming tools employed	Affordance
CAPE V2 client software components	Microsoft Visual Basic 6 (VB6)	VB6 has been designed to help programmers to create applications using component reuse and interaction with 3rd party API.
	Microsoft Access 2003	Provides a repository for user profile information to allow user experience to be tailored to each child's learning needs.
	Chilkat ActiveX VB6 sockets library	Chilkat was used as an alternative to TCL 2.0.1 to receive RFID-Bridge replies CAPE requests on TCP port 1066

Appendix F: RFID Bridge process in detail

Table F1: Read request process

Step number	Description
1	At the beginning of the process, the CAPE client (Simulator, CAPE1 or 2) calls a CAPE module setupConnect procedure with the request variable set to "r" (read request code). A TCP connection request is then initiated with RFID-Bridge, resulting in a TCP three way handshake.
2	Once the connection is established, CAPE sends the read request code "r" described in step number 1 to RFID-Bridge.
3	When RFID-Bridge receives a request code the data is compared to known codes ("r" = read request, "t" = test if symbol(s) have been removed from reader or "c" for close RFID-Bridge down).
4	If the read request is recognised the read subroutine will be initiated. This results in a request via the DLP hardware API for the reader to initiate a read request.
5	RFID provides power to the RFID antenna, which in turn powers the RFID tags on the reader. When this happens, each of the RFID tags, powered by the reader, begins to call out its ID. (In the single token API, the first symbol to call out was registered and all other symbols were ignored.)

As each RFID symbol attempts to communicate, it is registered and then told by the reader to be quiet. Once all tags have registered, RFID-Bridge sets the number of unread tags to 0 and the reader reports the symbol identity to the CAPE application. |
| 6 | RFID-Bridge processes each of the symbol requests and once task complete signal is given by the reader hardware RFID-Bridge begins to match Tag ID codes with those registered in its database. |

Step number	Description
7	Each tag ID is matched to Ids registered in the tag database. If the Id is registered in, the database RFID-Bridge reads the symbol name the tag represents and creates a delimited string with the name of the tag and a " _ " to denote the end of text, for example, "ISee_3_apple_" would denote "I See 3 apples". If the symbol does not exist an error, "E002" will be assigned and processing will finish. In addition, if the tag count is greater than 3 then an RFID-Bridge error of "E001" will be registered in the delimited string with all other symbol entries being removed.
8	Once processing has been completed RFID bridge sends the delimited data message to CAPE. When CAPE receives the data, it acknowledges receipt.
9	On receipt of a data, acknowledgment received message RFID-Bridge sends back a close session and terminates the session in its memory space.
10	On receipt of the close session, instruction from RFID-Bridge CAPE removes the TCP connection process from memory and processes the data message.

Step number	Description
11	The data message is stripped out of the delimited message and matched to the following criteria: a. Is the dataMessage "NONE". This message is only sent at the end of a test if symbol has been removed task (see Figure 7 for further details) b. Is the dataMessage an error "E001"? This error will result in the variable wrong being incremented to 1. When wrong = 1 the next video content to be played will be the wrong symbol content. c. Is the dataMessage an error "E002"? If this error is detected a pop-up error is sent to screen stating "symbol is not registered in database, please contact CAPE administrator" and When wrong = 1. d. The dataMessage contains all of the correct symbols requested the correct variable is set to 1 e. The dataMessage contains one or more incorrect symbols resulting in When wrong = 1 The dataMessage contains either "ISee_Finish_" or "Finish_" which will result in the quit variable being incremented to 1
12	CAPE activates one of the following tasks: a. If the wrong variable has been set to 1 and the error was an incorrect symbol selection or error "E001" the wrong symbol content is played. However, if error "E002" has been set then an error dialog box describing the error "symbol not registered in database" will be shown. In this instance, the system will not continue until the OK button is clicked on the dialog box, resulting in the wrong symbol content being played. b. If the correct variable is set to 1 then CAPE will play the correct content for that lesson If the quit variable has been set to 1 then the system will call the finish sub routine in CAPE.

Step number	Description
13	CAPE activates one of the following tasks: a. If the wrong variable has been set to 1 and the error was an incorrect symbol selection or error "E001" the wrong symbol content is played. However, if error "E002" has been set then an error dialog box describing the error "symbol not registered in database" will be shown. In this instance, the system will not continue until the OK button is clicked on the dialog box, resulting in the wrong symbol content being played. b. If the correct variable is set to 1 then CAPE will play the correct content for that lesson If the quit variable has been set to 1 then the system will call the finish sub routine in CAPE.

Table F2: testing for symbol removal

Step number	Description
1	At the beginning of the process CAPE client (Simulator, CAPE1 or 2) creates, a setupConect procedure call with the request variable set to "t" (test request code). A TCP connection request is then initiated with RFID-Bridge resulting in a TCP three way handshake.
2	Once the connection is established, CAPE sends the read request code "t" to RFID-Bridge.
3	When RFID-Bridge receives a request code the data is compared to known codes ("r" = read request, "t" = test if symbol(s) have been removed from reader or "c" for close RFID-Bridge down).
4	When the test request has been recognised and the test sub routine has been initiated a request is generated using the DLP hardware API. This is sent to the reader to initiate a read request. RFID_Reader now enters a listen for response cycle.
5	The read request continues until RFID tags are removed from the reader. When tags are on the reader, the reader will report the tag ID to RFID-Bridge. When all of the RFID tags have been removed from the reader the DLP hardware API will set tag count to 0 and send a task complete signal to RFID_Reader (in this case an empty string).
6	RFID-Bridge will continue to listen for responses until an empty string is received from the reader. Once this is detected, the task complete variable in RFID-Bridge is set to 1.

Step number	Description
7	When task complete is set to 1 RFID-Bridge assesses if the task being run is a read or a test request. If test request is active, the delimited string is set to "NONE".
8	RFID-Bridge then assess the error code, if error is equal to 0 then the dataMessage is set to the delimited data "NONE"
9	The dataMessage is sent to CAPE
10	On receipt of a data, acknowledgment received message RFID-Bridge sends back a close session and terminates the session in its memory space.
11	On receipt of the close session, instruction from RFID-Bridge CAPE removes the TCP connection process from memory and processes the data message.
12	When a "NONE" data message is received CAPE sets dataMessage to "", sets the symbol visibility to false (hiding the symbols on screen), sets the symbolRemove variable to 0 (so CAPE will not request a symbol remove again in this cycle), checks the database for the next symbol to be used and loads the new task.

Appendix G: RFID Bridge code (CAPE V2)

Option Explicit

Dim DLPObject As Object

Dim accSocket As Object

Dim connectedSocket As Object

Dim listenSocket As Object

Dim RetCode As Integer

Dim rs As ADODB.Recordset

Dim oConnection As ADODB.Connection 'Define the ADODB Connection

Dim resultSet As String

Private Declare Sub Sleep Lib "kernel32" (ByVal dwMilliseconds As Long)


```
 Sub Main()
        'Create the object
        Set accSocket = CreateObject("Chilkat.Socket")
        Set connectedSocket = CreateObject("Chilkat.Socket")
        Set listenSocket = CreateObject("Chilkat.Socket")
        Set connectedSocket = CreateObject("Chilkat.Socket")
        'Set-up a multi-tag DLP object for reading tags
        Set DLPObject = CreateObject("DLPMultiTag.DLPRWTags")
        'Open the DLP Read port
        RetCode = DLPObject.OpenPort(1, 1, 1)
        'Launch the TCP listening port
        testConect
End Sub
'Read the Tag ID
Private Function ReadCard() As String
        'Defines our BSTR
        Dim stCardID As String
```

```vb
        Dim stCarVal As String

        Dim retValue As String

        Dim varTags() As Variant

        'Call across COM passing the string

        varTags() = Array(DLPObject.ReadAllTags())

        stCardID = Join(varTags(0), "")

        'Display the string in the box

        If stCardID = "" Then

                stCarVal = "NONE"

        Else

                stCarVal = stCardID

        End If

        ReadCard = stCarVal

 End Function

Private Sub Cancel()

        RetCode = DLPObject.ClosePort()

        End

End Sub

Public Sub testConect()

        Dim receivedMsg As String

        Dim closeSession As String

        Dim success As Long

        success = listenSocket.UnlockComponent("PAULHESocket_VGttMBgzAZAj")

        If (success <> 1) Then

                MsgBox listenSocket.LastErrorText

                Exit Sub

        End If

        'Bind to a port and listen for incoming connections:

        'Listen on port 1066 for 25 pending connection requests
```

```vb
success = listenSocket.BindAndListen(1066, 25)

If (success <> 1) Then

        MsgBox listenSocket.LastErrorText

        Exit Sub

 End If

closeSession = "h"

While closeSession <> "c"

Set connectedSocket = listenSocket.AcceptNextConnection(0)

If (connectedSocket Is Nothing) Then

        MsgBox listenSocket.LastErrorText

        Exit Sub

End If

' Set maximum timeouts for reading an writing (in millisec) system will wait
for maximum of 24hrs

connectedSocket.MaxReadIdleMs = 86400000

connectedSocket.MaxSendIdleMs = 86400000

 ' Read the Tag ID

receivedMsg = connectedSocket.ReceiveString()

If (receivedMsg = vbNullString) Then

        MsgBox connectedSocket.LastErrorText

        Exit Sub

End If

If (receivedMsg = "r") Then

        Dim stCardID As String

        Dim cardValue As Integer

        Dim cardVal As String

        Dim count As Integer

        Dim stValLong As Long

        Dim tagOutput(3) As String

        Dim tagLength As Integer
```

322

```vb
Dim countDataSet As Integer

Dim tagOne As String

Dim tagTwo As String

Dim tagThree As String

Dim tagCounter As Integer

Dim tagSendCounter As Integer

Dim dataStream As String

Dim data As String

Dim dataError As String

Dim dataOne As String

Dim dataTwo As String

Dim dataThree As String

Dim dataStringTestOne As String

Dim dataStringTestTwo As String

Dim dataStringTestThree As String

Dim testPositive As Integer

Dim strConnection As String 'Define the connection string for use in
the ADODB Connection

Set oConnection = New ADODB.Connection

strConnection = "Provider=Microsoft.Jet.OLEDB.4.0;Data
Source=C:\RFID-Bridge\Database\tag.mdb"

oConnection.CursorLocation = adUseClient

'Set the connection string

oConnection.ConnectionString = strConnection

'Set the mode of the connection

oConnection.Mode = adModeReadWrite

'Open the Connection

oConnection.Open

stValLong = 1

cardVal = "NONE"

countDataSet = 0
```

323

```
            dataError = ""

             While stValLong < 10

            cardVal = Module1.ReadCard

            stValLong = Len(cardVal)

            Sleep 500

        Wend

        tagSendCounter = 0

        tagCounter = 0

        tagLength = Len(cardVal)

        If tagLength > 48 Then

        tagOutput(0) = "E001"

        tagCounter = 4

End If

If tagLength = 48 Then

        tagThree = Right$(cardVal, 16)

        tagTwo = Mid$(cardVal, 17, 16)

        tagOne = Left$(cardVal, 16)

        tagOutput(2) = tagThree

        tagOutput(1) = tagTwo

        tagOutput(0) = tagOne

        tagCounter = 3

End If

If tagLength = 32 Then

        tagTwo = Mid$(cardVal, 17, 16)

        tagOne = Left$(cardVal, 16)

        tagOutput(1) = tagTwo

        tagOutput(0) = tagOne

        tagCounter = 2

End If

If tagLength = 16 Then
```

```
                tagOne = Left$(cardVal, 16)

                tagOutput(0) = tagOne

                tagCounter = 1

        End If


        tagSendCounter = tagCounter

        dataOne = ""

        dataTwo = ""

        dataThree = ""

        While tagCounter > 0 And tagCounter < 4

                cardVal = ""

                cardVal = tagOutput(tagCounter - 1)

                Set rs = New ADODB.Recordset 'this will be the rs

                Dim strSQL As String 'this the source

                strSQL = "Select TagName, Order From TagIndex Where TagRef = '" &
        cardVal & "'" 'Get all records from tblExample

                rs.Open strSQL, oConnection, adOpenStatic, adLockBatchOptimistic,
        adCmdText

                If rs(1) = 1 Then

                        dataOne = dataOne + rs(0) + "_"

                ElseIf rs(1) = 2 Then

                        dataTwo = dataTwo + rs(0) + "_"

                Else

                        dataThree = dataThree + rs(0) + "_"

                End If

                rs.Close 'Close the recordset never leave it open!

                Set rs = Nothing 'clear the rs variable

                tagCounter = tagCounter - 1

                countDataSet = countDataSet + 1

        Wend

        If tagCounter = 4 Then
```

```vb
        dataError = "E001"
End If

Sleep 800

End If

testPositive = 0

data = ""

If (receivedMsg = "t") Then

stValLong = 5

While stValLong > 4

cardVal = Module1.ReadCard

stValLong = Len(cardVal)

Sleep 500

If stValLong < 5 Then

testPositive = 1

data = "NONE"

End If

Wend

End If

' Send a RFID Token ID message to the client:

Dim countMeUp As Integer

countMeUp = 0

If Len(dataError) < 1 And testPositive = 0 Then

data = data + dataOne + dataTwo + dataThree

End If

If Len(dataError) > 1 Then

data = dataError

End If

success = connectedSocket.SendString(data)

data = ""

If (success <> 1) Then
```

```vb
        MsgBox connectedSocket.LastErrorText

        Exit Sub

        End If

        closeSession = receivedMsg

        connectedSocket.Close 200

    Wend

    If (receivedMsg = "c") Then

    ' Close the connection with the client.

    Module1.Cancel

    End If

End Sub

Private Sub Form_QueryUnload(Cancel As Integer, UnloadMode As Integer)

    On Error Resume Next

    If oConnection.State = adStateOpen Then 'Check the open state of the
connection

    oConnection.Close 'If it is open then close it

    End If

    'Set oConnection and rs to nothing to prevent memory leak problems

    Set oConnection = Nothing

    Set rs = Nothing

End Sub
```

Appendix H: CAPE V2 code structure

Management screen

```
Option Explicit

        Public userName As String

        Public testingSymbol As Integer

        Public learnSymbol As Integer

        Public learningSymbol As Integer

        Public errorLimit As Integer

        Public contentPath as String


Private Sub Close_Click(Index As Integer)

        Call Communicate.setUpConect("c")

        Unload manager

End Sub


Private Sub RFID_Launch()

        Shell ("c:\RFID-BRIDGE\bin\RFID-BRIDGE.exe")

End Sub

Private Sub Test4-4()

        testingSymbol = 4

        learnSymbol = 4

        learningSymbol = 4

        contentPath = "c:\CAPE\content\"

        Unload manager

End Sub

Private Sub Test4-4Advanced()

        testingSymbol = 4

        learnSymbol = 4
```

```vb
        learningSymbol = 4

        contentPath = "c:\CAPE\content1\"

        Unload Manager

End Sub

Private Sub Command3_Click()

        testingSymbol = 4

        learnSymbol = 4

        learningSymbol = 4

        contentPath = "c:\CAPE\content\"

        Unload Manager

End Sub

Private Sub Launch_RFIDReader(Index As Integer)

        Call RFID_Launch

End Sub

Private Sub Command5_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-5SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub Command6_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-6SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub Command7_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-7SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub Command8_Click()
```

```vb
        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-8SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub Command9_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\UserDBEdit.exe", 1)

        Unload Manager

End Sub

Private Sub learn2_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-2SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub learn3_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-3SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub learn4_Click()

        Dim RetVal

        RetVal = Shell("c:\CAPECS\bin\CAPE-initial-4SymbolMgr.exe", 1)

        Unload Manager

End Sub

Private Sub Open_Click(Index As Integer)

        testingSymbol = 2

        learnSymbol = 2

        learningSymbol = 2

        contentPath = "c:\CAPE\content\"

        Unload Manager
```

330

```
End Sub

Private Sub testLearnAdv_Click()

        testingSymbol = 2

        learnSymbol = 2

        learningSymbol = 2

        contentPath = "c:\CAPE\content1\"

        Unload Manager

End Sub


```

User selection screen

```
Option Explicit

        Public userName As String

        Private Sub Close_Click(Index As Integer)

                Unload Form1

                Form2.Visible = False

                Dim RetVal

                RetVal = Shell("c:\CAPECS\bin\CAPE4-Manager.exe", 1)

                Unload Form2

        End Sub

        Public Sub List1_Click()

                Dim data As String

                Dim rs As New ADODB.Recordset

                Dim strConnectionString As String

        Dim strSQL As String

        Dim strID As String

        Dim strName As String

        On Error GoTo Handler:

        strConnectionString = "Provider=Microsoft.Jet.OLEDB.4.0;" _

                & "Data Source=c:\capecs\database\participant.mdb;Mode=Read;"
```

```
        strSQL = "select * from participant"

        rs.Open strSQL, strConnectionString

                If Not (rs.EOF And rs.BOF) Then

                        rs.MoveFirst

                        Do While Not rs.EOF

                                strID = rs.Fields(0).Value

                                strName = rs.Fields(1).Value

                                Text1.Text = strName

                                Call AddToListBox(strID, strName)

                                rs.MoveNext

                        Loop

                Else

                        MsgBox "No records found."

                End If

                My_Exit_Sub:

                On Error Resume Next

                rs.Close

                Set rs = Nothing

                Exit Sub

                Handler:

                MsgBox "Error " & Err.Number & ": " & Err.Description

                Resume My_Exit_Sub

End Sub

Private Sub AddToListBox(ByVal strID As String, ByVal strName As String)

        MsgBox "Code to add to list box executes now."

End Sub

Private Sub Form_Load()

        dta_proj.DatabaseName = "C:\CAPECS\database\UserData.mdb"

        dta_proj.RecordSource = "Participant"

        userName = Text1.Text
```

```vb
        'Form1.Visible = False

End Sub

Private Sub Open_Click(Index As Integer)

        userName = Text1.Text

        Load Form1

        Form1.Visible = True

        Form1.Picture1.Visible = False

        Form1.Picture2.Visible = False

        Form1.Picture3.Visible = False

        Unload Form2

End Sub
```

Commboard function

```vb
Public Function comBoard(symbol1 As String, symbol2 As String, symbol3 As String)

        If LenB(symbol1) <> 0 Then

                Picture1.Picture = LoadPicture(symbol1)

                Picture1.Visible = True

         Else

                Picture1.Visible = False

         End If

         If LenB(symbol2) <> 0 Then

                Picture2.Picture = LoadPicture(symbol2)

                Picture2.Visible = True

         Else

                Picture2.Visible = False

         End If


         If LenB(symbol3) <> 0 Then

                Picture3.Picture = LoadPicture(symbol3)
```

```vb
                Picture3.Visible = True

        Else

                Picture3.Visible = False

        End If

 End Function


DataEdit Function

Private Sub dataEdit(dtest As String)

        Dim CallIt As Long

        Dim textOut1 As Long

        Dim textOut2 As Long

        Dim textOut As String

        Dim textOut3 As String

        Dim output As String

        dataOut = ""

        dataOut2 = ""

        dataOut3 = ""

        CallIt = CountChars(dtest, 95) '95 is the ascii code for the _ data delimiter

        textOut2 = 1

        'find out how many symbols selected (1-3 valid symbols) and breakdown
into symbol names without delimiter

        If CallIt = 1 Then

                textOut1 = InStr(1, dtest, "_", 1)

                dataOut = Mid$(dtest, 1, textOut1 - 1)

        ElseIf CallIt = 2 Then

                textOut1 = InStr(1, dtest, "_", 1)

                textOut2 = InStr(textOut1 + 1, dtest, "_", 1)

                dataOut = Mid$(dtest, 1, textOut1 - 1)

                dataOut2 = Mid$(dtest, textOut1 + 1, textOut2 - textOut1 - 1)

            Else
```

334

```
            textOut1 = InStr(1, dtest, "_", 1)

            textOut2 = InStr(textOut1 + 1, dtest, "_", 1)

            textOut3 = InStr(textOut2 + 1, dtest, "_", 1)

            dataOut = Mid$(dtest, 1, textOut1 - 1)

            dataOut2 = Mid$(dtest, textOut1 + 1, textOut2 - textOut1 - 1)

            dataOut3 = Mid$(dtest, textOut2 + 1, textOut3 - textOut2 - 1)

        End If
```

'add .jpg extension so that image file can be correctly called. dataOut variables will then be used as references to

   user selected symbols via RFID-Bridge

```
    If CallIt = 1 Then

        dataOut = dataOut + ".jpg"

        ElseIf CallIt = 2 Then

        dataOut = dataOut + ".jpg"

    dataOut2 = dataOut2 + ".jpg"

Else

        dataOut = dataOut + ".jpg"

        dataOut2 = dataOut2 + ".jpg"

        dataOut3 = dataOut3 + ".jpg"

    End If

End Sub
```

The checkOutPut sub routine

```
Private Sub checkOutPut()

        Dim opt1 As String

        Dim opt2 As String

        Dim opt3 As String

        Call setUpConect("r") 'request RFID-Bridge to listen for a new symbol
        selection

        Call dataEdit(receivedMsg) 'when RFID-Bridge responds with a symbol
        selection call dataEdit to break data string into
```

```
'1 to 3 symbols selected

opt1 = ""

opt2 = ""

opt3 = ""

'assign symbol output from dataOut variables to opt variables including the
correct content path for lesson being taught

If Len(dataOut) > 1 Then

      opt1 = contentPath + dataOut

 End If

 If Len(dataOut2) > 1 Then

      opt2 = contentPath + dataOut2

 End If

 If Len(dataOut3) > 1 Then

      opt3 = contentPath + dataOut3

 End If

 Call Me.comBoard(opt1, opt2, opt3)
End Sub
```

Video set-up sub routine

```
Private Sub video(inputData As String, item As Integer)

      Dim count As Integer

      Dim stValLong As Long

      Dim tagOutput(3) As String

      Dim tagLength As Integer

      Dim countDataSet As Integer

      Dim tagOne As String

      Dim tagTwo As String

      Dim tagThree As String

      Dim tagCounter As Integer

      Dim tagSendCounter As Integer
```

```
Dim dataStream As String

Dim data As String

Dim dataError As String

Dim dataOne As String

Dim dataTwo As String

Dim dataThree As String

Dim dataStringTestOne As String

Dim dataStringTestTwo As String

Dim dataStringTestThree As String

Dim testPositive As Integer

Dim strConnection As String 'Define the connection string for use in the
ADODB Connection

Dim rs As New ADODB.Recordset

Set oConnection = New ADODB.Connection

strConnection = "Provider=Microsoft.Jet.OLEDB.4.0;Data
Source=C:\CAPE\Database\UserData.mdb"

oConnection.CursorLocation = adUseClient

'Set the connection string

oConnection.ConnectionString = strConnection

'Set the connection mode

oConnection.Mode = adModeReadWrite

' Open the Connection

oConnection.Open

cardVal = inputData

stValLong = 1

countDataSet = 0

dataError = ""

Set rs = New ADODB.Recordset 'this will be the rs

Dim strSQL As String 'this the source

strSQL = "Select * From ImageName Where ImageFile = '" & cardVal & "'"
'Get all records from tblExample
```

337

```
        rs.Open strSQL, oConnection, adOpenStatic, adLockBatchOptimistic,
        adCmdText

    tokenName = rs(1)

    imageFile = rs(2)

    task = rs(3)

    model = rs(4)

    request = rs(5)

    wrong = rs(6)

    correct = rs(7)

    test = rs(8)

    rs.Close 'Close the recordset

    Set rs = Nothing 'clear the rs variable

    rowCount = rowCount + 1

    cardVal = ""

    cardVal = rowCount & ".jpg"
End Sub
```

The filmTimer sub routine

```
Private Sub filmTimer()

    Dim movieTime As Long, percentageDone As Integer

    Dim movieTime2 As Long, percentageDone2 As Integer

    movieTime = QuickTimeSimpleObj.movieTime

    If movieTime <> 0 Then 'if there is a .mov file that is > 0 seconds in length
play movie

        percentageDone = 0

        percentageDone = Int((movieTime / duration) * 100) 'calculate the
    percentage of movie time has been playing

        sldProgress.Value = movieTime

        Picture4.Visible = False 'hide the Picture4 image

        If percentageDone = 100 Then 'if the movie has completed stop the
    movie object and clear up memory

        QuickTimeSimpleObj.StopMovie
```

count1 = 1

If removeSymbol = 1 Then 'if CAPE is waiting for symbol removal stop CAPE from offering another selection

symbolSelect = 0

Else

symbolSelect = 1 'if symbol removal complete then offer another symbol selection

End If

If readTokens = 1 Then 'if read tokens routine required then process token read and check if user wants to

'finish using "Finish" or symbol sentence "ISee Finish "

Call checkOutPut

readTokens = 0

If receivedMsg = "Finish_" Or receivedMsg = "Isee_Finish_" Then

wantToFinish = 1 'run finish routine

End If

End If

If testTokens = 1 Then 'check if symbol removal task is active

If receivedMsg <> "NONE" Then 'if symbol has not been removed then call symbol remove test

Call setUpConect("t")

End If

If receivedMsg = "NONE" Then 'RFID-Bridge detects symbol removal hide the symbol images in

'CAPE

Picture1.Visible = False

Picture2.Visible = False

Picture3.Visible = False

testTokens = 0

removeSymbol = 0

339

```
                        startup = 0


                  If wantToFinish = 1 Then 'if user has requested finish
    set quit variable to 1

                        quit = 1

                  End If

            End If

      End If

      If quit = 2 Then 'when finish sequence complete in CAPE forward
    user to Form3 and clear memory

            'of any processes not now required

            Form3.userName = Manager.userName

            QuickTimeSimpleObj.CloseMovie

            Form1.Visible = False

            Form3.Visible = True

            Timer1.Enabled = False

            wantToFinish = 0

            receivedMsg = ""

            Unload Form1

      End If

    End If

    End If

End Sub
```

The main runtime code for Lesson

```
Private Sub Timer1_Timer()


    test = ""

    request = ""

    wrong = ""

    correct = ""
```

340

```
model = ""

filePath = contentPath


If testingDataInfo(0) = "0.jpg" Then

firstTime = 1

Else

firstTime = 0

. End If

If progressTestNum > 0 Then

        If testingDataInfo(progressCountTest) = "0.jpg" Then

                browse (filePath & "NewSymbolIntroductionTest.mov")

                QuickTimeSimpleObj.PlayMovie

                progressTestNum = 0

        Else

                Call video(testingDataInfo(progressCountTest),
progressCountTest) 'get test data

        End If

End If

If progressLearningNum > 0 And progressTestNum = 0 Then

        If learningDataInfo(progressCountLearning) = "0.jpg" Then

                progressLearningNum = 0

        Else

                Call video(learningDataInfo(progressCountLearning),
progressCountLearning) 'get data not yet taught

        End If

End If

If progressLearningNum = 0 And progressTestNum = 0 Then

        If introNewLearn = 0 Then

                Call video(learnDataInfo(progressCountLearn),
progressCountLearn)

        End If
```

341

```
        End If

    If testOutput = 2 Then

        testOutput = 0

        symbolSelect = 0

        pauseCode = 1

        If firstTime = 0 Then

                browse (filePath & "HelloTest.mov")

                QuickTimeSimpleObj.PlayMovie

        Else

                learning = 0

                browse (filePath & "HelloInitial.mov")

                QuickTimeSimpleObj.PlayMovie

        End If

                startup = 1

                removeSymbol = 0

                quit = 0

                count1 = 1

                testOutput = 0

                readTokens = 0

                answerCorrect = 1

        End If

        Call filmTimer

        If quit = 0 Then '************** while quit does not = 1 then continue
lesson *******************

                If symbolSelect = 1 Then '************* if symbolSelect = 1 then
offer symbol selection ***********

                        If testForLoad > 0 And learning = 0 And testing = 0
Then

                                If testForLoad > 0 And answerCorrect = 1 Then

                                        'MsgBox "in testforload"

                                        modelTask = 1
```

342

```
                        count1 = 1

                        testForLoad = testForLoad - 1

                End If

        End If

        If testing > 0 Or learning > 0 And firstTime = 0 Then

                If testing = 0 And learning > 0 Then

                        chooseAToken = 1

                        count1 = 1

                        removeSymbol = 0

                        modelTask = 0

                        If answerCorrect = 1 Then

                                learning = learning - 1

                        End If

                Else

                        testSymbol = 1

                        count1 = 1

                        removeSymbol = 0

                        modelTask = 0


                        If answerCorrect = 1 Then

                                testing = testing - 1

                        End If

                End If

        End If


        If answerWrong > 1 Then

                modelTask = 1

                count1 = 1

                answerWrong = 0

        End If

                        343
```

```
If modelTask = 1 And count1 = 1 Then '******* if
modelTask = 1 then this is the first lesson so model the symbol task and
don't score result *******************

                    count1 = 0

                    pauseCode = 1

                    browse (filePath & model)

                    QuickTimeSimpleObj.PlayMovie

                    chooseAToken = 1

                    readTokens = 0

                    removeSymbol = 0

                    modelTask = 0

                    answerCorrect = 0

            End If

            If testSymbol = 1 And count1 = 1 Then '******** this is
the first part of a a lesson but not first exposure to system - score lesson
*******************

                    count1 = 0

                    browse (filePath & test)

                    QuickTimeSimpleObj.PlayMovie

                    symbolSelect = 0

                    removeSymbol = 0

                    readTokens = 1

            End If

            If chooseAToken = 1 And count1 = 1 Then '*************
quit has not been selected **********************

                    count1 = 0

                    browse (filePath & request)

                    QuickTimeSimpleObj.PlayMovie

                    symbolSelect = 0

                    readTokens = 1

            End If

            Dim testVar As String
```

344

```vb
                        Dim testTwoVar

                        Dim testThreeVar As String

                        testVar = "Isee_" & tokenName

                        testTwoVar = tokenName & task

                        testThreeVar = testVar & task

                        If receivedMsg = tokenName Or receivedMsg = testVar
Or receivedMsg = testTwoVar Or receivedMsg = testThreeVar And
modelTask = 0 Then '**************** check that participant has selected
correct symbol

                                count1 = 0

                                browse (filePath & correct)

                                QuickTimeSimpleObj.PlayMovie

                                symbolSelect = 0

                                removeSymbol = 1

                                answerCorrect = 1

                                answerWrong = 0


                                If progressTestNum > 0 Then

                                        progressTestNum = progressTestNum - 1

                                        If progressCountTest < 3 Then

                                                progressCountTest =
progressCountTest + 1

                                        End If

                                End If

                                If progressLearningNum > 0 And
progressTestNum = 0 Then

                                        progressLearningNum =
progressLearningNum - 1

                                        If progressCountLearning < 3 Then

                                                progressCountLearning =
progressCountLearning + 1

                                        End If

                                End If
```

345

```
                              If progressLearningNum = 0 And
progressTestNum = 0 Then

                                   If progressCountLearn < 3 Then

                                        progressCountLearn =
progressCountLearn + 1

                                   Else

                                        progressCountLearn = 0

                              End If

                         End If

                    End If

                    If introNewLearn = 1 And learning = 0 And removeSymbol = 0
Then

                         introNewLearn = 0

                         symbolSelect = 0


                         If firstTime = 0 Then

                              browse (filePath &
"NewSymbolIntroduction.mov")

                                   QuickTimeSimpleObj.PlayMovie

                         End If

                         startup = 1

                         removeSymbol = 0

                         quit = 0

                         modelTask = 1

                         readTokens = 0

                         answerCorrect = 1

                         count1 = 1

                    End If


                    If receivedMsg = "Finish_" Or receivedMsg = "Isee_Finish_"
          Then

                         removeSymbol = 1
```

```
                        count1 = 1

                        answerWrong = 0

                        answerCorrect = 0

              End If


        If receivedMsg <> tokenName And receivedMsg <> testVar
And receivedMsg <> testTwoVar And receivedMsg <> testThreeVar
And receivedMsg <> "Finish_" And receivedMsg <> "Isee_Finish_"
Then

                        If receivedMsg <> "" And receivedMsg <> "NONE"
    Then

                                count1 = 0

                                browse (filePath & wrong)

                                QuickTimeSimpleObj.PlayMovie

                                symbolSelect = 0

                                removeSymbol = 1

                                receivedMsg = ""

                                answerWrong = answerWrong + 1

                                answerCorrect = 0

                        End If

                End If

        End If

    End If

    If removeSymbol = 1 And count1 = 1 Then '************* request remove
symbol *********************

            count1 = 0

            browse (filePath & "removesymbol.mov")

            QuickTimeSimpleObj.PlayMovie

            symbolSelect = 0

            testTokens = 1

            If quit = 0 Then

                    removeSymbol = 0

                                347
```

```
            End If

            If answerCorrect = 1 And testing = 0 And introNewLearn = 2 Then

                    introNewLearn = 1

            End If

     End If

   If quit = 1 And removeSymbol = 1 Then

                count1 = 1

    End If

    If quit = 1 And count1 = 1 Then

            count1 = 0

            quit = 2

            symbolSelect = 0

            browse (filePath & "GoodbyeNew.mov")

            QuickTimeSimpleObj.PlayMovie

        End If

End Sub
```

Appendix I: User testing by 'Matthew'

Table I1: Example of user testing by 'Matthew'

Task	Task Title	Task Description	Success Criteria	notes	Test result
1.0	Hello phase	Observe Hello phase	Hello phase completes SM hello video and VT introduction utterance in correct order without any error messages		Pass
2.0	Task introduction	Observe task introduction from VT	• Participant takes note of introduction from VT: • shows understanding of task (sentence utterance length is short enough to avoid auditory processing issues) • Sentence is understood by participant • Utterance is slow enough for participant to interpret • is not distracted by other visual stimuli while VT is speaking		Pass

Task	Task Title	Task Description	Success Criteria	notes	Test result
3.0	Symbol selection task	VT asks participant to select a symbol from their PECS	• correct symbol representations are shown on screen		Pass
3.1		Participant is given time to select symbol from PECS folder	• participant looks at symbol selection on screen • participant selects a symbol from the • folder that is represented on visual prompt • Selection time should be unlimited (no timeout error)		Pass
4.0	Symbol selection task	Participant selects symbol	• Symbol is easily accessible (Velcro does not stop symbol selection) • Symbol structure not damaged during selection		Pass

Task	Task Title	Task Description	Success Criteria	notes	Test result
4.1		RFID tag detection phase	• Symbol is detected by reader • Symbol description (such as "breakfast") is correctly reported to CAPE • RFID > CAPE message sent in timely manor • Correct selection video for symbol selected is played		Pass
5.0	Symbol removal task	CAPE requests participant to remove symbol from reader	• VT symbol removal audio request is played • RFID-Bridge receives "t" message to remove symbol • RFID reader begins tag read task		Pass

351

Task	Task Title	Task Description	Success Criteria	notes	Test result
5.1		Participant removes symbol from reader	• Participant reacts to task correctly • Time delay from symbol removal to thank you video is appropriate for user (500ms) • RFID-Bridge detects symbol removal • RFID > CAPE "NONE" message sent		Pass
6.0	The Yes/No task	Request participant to choose to select another symbol or finish	• Yes/No VT request is shown Yes/No symbols are shown		Pass
6.1		Participant is given time to select symbol from PECS folder	• participant looks at symbol selection on screen • participant selects a symbol from the folder that is represented on visual prompt • Selection time should be unlimited (no timeout error)		Pass

Task	Task Title	Task Description	Success Criteria	notes	Test result
6.2		Participant selects symbol	• Symbol is easily accessible (Velcro does not stop symbol selection) • Symbol structure not damaged during selection		Pass
6.3		RFID tag detection phase	• Symbol is detected by reader • Symbol description (such as "Yes") is correctly reported to CAPE • RFID > CAPE message sent in timely manor • Correct selection video for symbol selected is played	Symbol name set in CAPE filter was "Yes" and "yes" in tag.mdb Entry changed in filter to "breakfast". Retest now required..	Fail

Task	Task Title	Task Description	Success Criteria	notes	Test result
6.4		User selects "Yes"	• Correct symbol shown on screen • correct VT audio given • time delay appropriate for user (currently 500ms)		Pass
7.0	Symbol removal task	CAPE requests participant to remove symbol from reader	• VT symbol removal audio request is played • RFID-Bridge receives "t" message to remove symbol • RFID reader begins tag read task		Pass
7.1		Participant removes symbol from reader	• Participant reacts to task correctly • Time delay from symbol removal to thank you video is appropriate for user (500ms) • RFID-Bridge detects symbol removal • RFID > CAPE "NONE" message sent		Pass

354

Appendix J: CAPE V2 user guide

The main menu has been simplified. Further functionality has also been added as per Figure J1, below
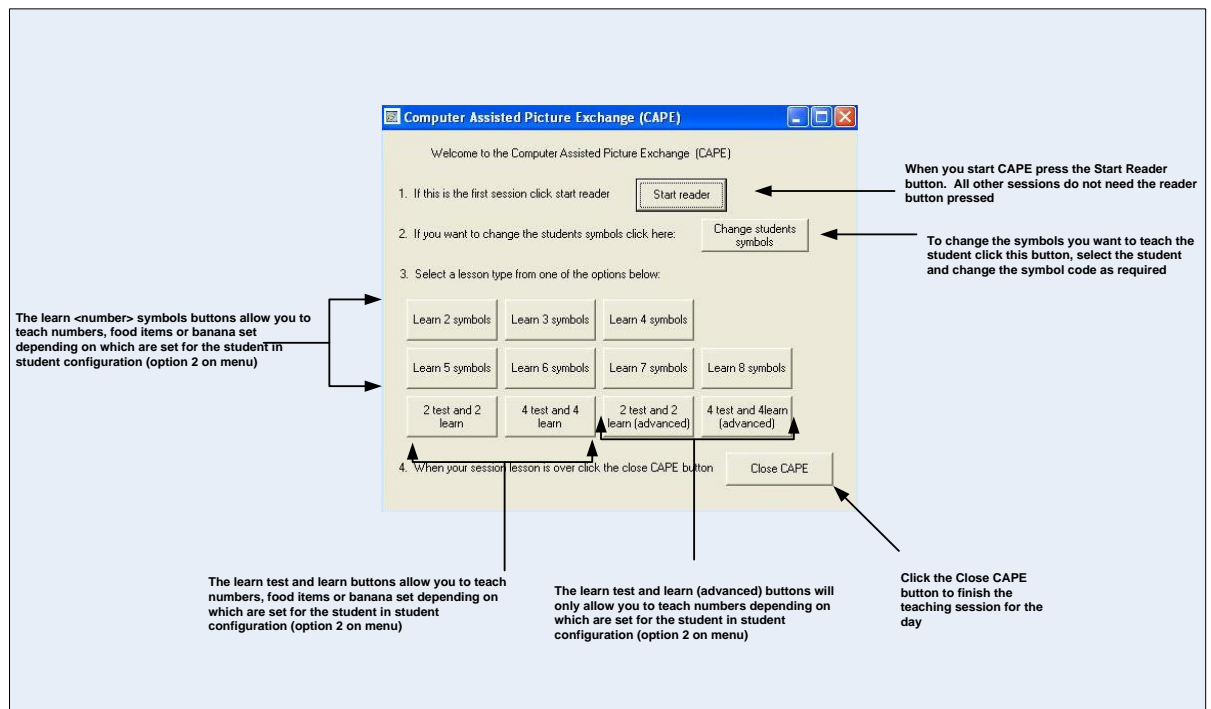
Figure J1: CAPE V2 main menu

Point 2 on the CAPE main menu allows you to change the symbols the student is currently learning. To do this, do the following:

1. Click on the 'Change Student Symbols' button.
2. Select the student configuration you wish to change
3. If you intend to use the '2 test and 2 learn' or 4 test and 4 learn (or the advanced options) then first modify the field 'Symbols being tested' to change which symbols will be tested in phase one of the session.
4. Now modify the 'New symbols (with modelling)' option.
5. If you are using the 'learn <number> Symbols' buttons then you will only need to edit the 'New symbols (with modelling)' symbols.
6. Once you have updated the student's configuration click onto another student to save the changes.
7. Please note when modifying the symbols you will teach ensure that eight numbers appear in each field and each symbol code is separated with a comma (including the last number) as per Figure I2 below. A full list of symbols and codes can be found in the tables below:

Figure J2: Student configuration window

Table J1: Example of symbol codes for use in CAPE V2

Symbol	Code		Symbol	Code
1	1,		koosh ball	1k,
2	2,		Three apples	3a,
3	3,		Four teddy bears	4tb,
4	4,		One banana	1b,
5	5,		Two bananas	2b,
6	6,		Three bananas	3b,
7	7,		Four bananas	4b,
8	8,			

Appendix K – teaching protocol, CAPE pilot study

Introduction

The aim of this protocol is to provide a consistent teaching approach during children's sessions in the pilot study. The pilot study will consist of two sessions; session one will be used as an introduction to the Computer Assisted Picture Exchange (CAPE) test environment. Session 2 will repeat the tasks introduced in session one but will use a different voice (either a synthetically generated or naturally recorded voice type). To ensure that a consistent teaching approach is used please follow the guidelines for each session below:

General guidance

1. You as the teacher are in control of the teaching session. If you feel that, the child is becoming distressed or wants to finish a session you may do so.
2. Always allow the child time to make an independent symbol selection. Only provide guidance either when the child indicates they need help or after a delay of 30 seconds to allow the child time to understand and make a choice.
3. The level of support provided should be enough to meet the child's needs. Any support provided should be faded out over the session. Initially a delay of 20 to 30 seconds can be used however as the session progresses the delay should be extended to 40 seconds before you intervene in a task
4. When prompting the child to select a symbol use the Makaton sign for "choose" if this is known to the child or circle the symbol folder with your hand but take care not to point to any one symbol as this may teach the child only to select a symbol that is indicated by you.
5. The child may finish the session by using the 'No' symbol when asked to choose during the Yes/No task.
6. If the child selects the wrong symbol during a selection request or is unsure, wait until the virtual tutor has told the child, they have made a mistake, wait 30 seconds and if necessary provide verbal or physical support to help the child complete the task correctly.
7. If the child elects to finish the session but later (but before they leave the session) indicate to you that they would like to continue then indicate the child's intention and the session will be restarted.

Specific guidance for each session is documented below:

Session 1

1. The teacher will direct the view of the child to the computer screen when the application begins. The virtual tutor will say hello as a greeting at the beginning of the session, when this happens point to the screen, wave and say hello as a way of directing attention to the onscreen content.
2. When virtual tutor asks for you to help Super Monkey choose a food or drink item select the banana symbol and place it on the reader. During symbol selection verbally describe your actions
3. When you are asked to complete a symbol tidy remove the symbol from the reader and place it in the symbol folder.
4. Virtual tutor will ask if you would like to continue using CAPE, please select the 'Yes' symbol, verbally describe what you are doing and place it on the reader (as you did with the symbol selection task).
5. When virtual tutor requests you select a symbol again invite the child you are supporting to make a symbol selection. During this and subsequent selections the child may require guidance and support, please follow the general guidance relating to fading of support.

Session 2

1. At the beginning of the session wave to the virtual tutor as per session one.
2. Allow the child to make an unsupported symbol selection. If the child either indicates or is observed to be unsure of the task after a 30 second delay then request the child to choose a symbol by signing and saying "choose" using Makaton (if known by the child).
3. If the child does not react to the selection request then aid the child by placing the child's hand on the symbol folder and repeating the phrase <child's name> "choose"

Appendix L - pilot study quantitative data

Table L1: pilot study quantitative data

Child	Voice type	Number of correctly selected symbols	Total length of time spent looking at CAPE V1 (Seconds)	Total time spent looking at the support teacher (seconds)	Mean time of response to VT request when visual prompt was given (in	Mean time of response to VT request when no visual
Brian	Synthetic	9	175	9	3	1
Brian	Natural	9	155	16	4	3
Alan	Synthetic	10	218	3	4	0.8
Alan	Natural	3	89	5	5	1
Charles	Synthetic	7	160	7	3	1
Charles	Natural	7	173	5	3	1

Child	Voice type	Number of correctly selected symbols	Total length of time spent looking at CAPE V1 (Seconds)	Total time spent looking at the support teacher (seconds)	Mean time of response to VT request when visual prompt was given (in seconds)	Mean time of response to VT request when no visual prompt given (in 1seconds)
David	Synthetic	12	257	5	2	3
David	Natural	6	282	8	4	30
Edward	Synthetic	5	208	4	1	2
Edward	Natural	4	225	2	7	2
Fiona	Synthetic	5	126	15	5	2
Fiona	Natural	3	152	16	7	3

Child	Voice type	Number of correctly selected symbols	Total length of time spent looking at CAPE V1 (Seconds)	Total time spent looking at the support teacher (seconds)	Mean time of response to VT request when visual prompt was given (in seconds)	Mean time of response to VT request when no visual prompt given (in 1seconds)
George	Synthetic	1	83	20	13	2
George	Natural	0	55	4	13	0.9
Henry	Synthetic	5	368	8	8	0.83
Henry	Natural	2	320	4	16	3

Appendix M: Statistical analysis of pilot study quantitative Data

Table M1: Number of symbols selected: Natural voice vs. Synthetic voice

Ranks

		N	Mean Rank	Sum of Ranks
Synthetic_symbol_appropriate - Natural_symbol_appropriate	Negative Ranks	0[a]	.00	.00
	Positive Ranks	6[b]	3.50	21.00
	Ties	2[c]		
	Total	8		

a. Synthetic_symbol_appropriate < Natural_symbol_appropriate
b. Synthetic_symbol_appropriate > Natural_symbol_appropriate
c. Synthetic_symbol_appropriate = Natural_symbol_appropriate

Test Statistics[b]

	Synthetic_symbol_appropriate - Natural_symbol_appropriate
Z	-2.207[a]
Asymp. Sig. (2-tailed)	.027

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

Table M2: Time looking in the Zone: Natural voice vs. Synthetic voice

Ranks

		N	Mean Rank	Sum of Ranks
Synthetic_look_at_screen - Natural_look_at_screen	Negative Ranks	4[a]	3.00	12.00
	Positive Ranks	4[b]	6.00	24.00
	Ties	0[c]		
	Total	8		

a. Synthetic_look_at_screen < Natural_look_at_screen
b. Synthetic_look_at_screen > Natural_look_at_screen
c. Synthetic_look_at_screen = Natural_look_at_screen

Test Statistics[b]

	Synthetic_look_at_scree n - Natural_look_at_screen
Z	-.840[a]
Asymp. Sig. (2-tailed)	.401

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Table M3: Time Looking at Teacher: Natural voice vs. Synthetic voice

Ranks

		N	Mean Rank	Sum of Ranks
Synthetic_look_at_teac her - Natural_look_at_teache r	Negative Ranks	4[a]	4.25	17.00
	Positive Ranks	4[b]	4.75	19.00
	Ties	0[c]		
	Total	8		

a. Synthetic_look_at_teacher < Natural_look_at_teacher

b. Synthetic_look_at_teacher > Natural_look_at_teacher

c. Synthetic_look_at_teacher = Natural_look_at_teacher

Test Statistics[b]

	Synthetic_look_at_teache r - Natural_look_at_teacher
Z	-.140[a]
Asymp. Sig. (2-tailed)	.889

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Table M4: The mean response time by a child when an onscreen visual prompt was given by CAPE V1 to respond to the virtual tutor request

		N	Mean Rank	Sum of Ranks
Synthetic_ave_speed_ with_prompt - Natural_ave_speed_wit h_prompt	Negative Ranks	8[a]	4.50	36.00
	Positive Ranks	0[b]	.00	.00
	Ties	0[c]		
	Total	8		

a. Synthetic_ave_speed_with_prompt < Natural_ave_speed_with_prompt

b. Synthetic_ave_speed_with_prompt > Natural_ave_speed_with_prompt

c. Synthetic_ave_speed_with_prompt = Natural_ave_speed_with_prompt

Test Statistics[b]

	Synthetic_ave_speed_with_pro mpt - Natural_ave_speed_with_prom pt
Z	-2.521[a]
Asymp. Sig. (2-tailed)	.012

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Table M5: The mean response time by a child when no visual prompt was given
by CAPE V1 for virtual tutor requests

Ranks

		N	Mean Rank	Sum of Ranks
Synthetic_ave_speed_ without_prompt - Natural_ave_speed_wit hout_prompt	Negative Ranks	6[a]	4.33	26.00
	Positive Ranks	1[b]	2.00	2.00
	Ties	1[c]		
	Total	8		

a. Synthetic_ave_speed_without_prompt < Natural_ave_speed_without_prompt

b. Synthetic_ave_speed_without_prompt > Natural_ave_speed_without_prompt

c. Synthetic_ave_speed_without_prompt = Natural_ave_speed_without_prompt

Test Statistics[b]

	Synthetic_ave_speed_without_ prompt - Natural_ave_speed_without_pr ompt
Z	-2.028[a]
Asymp. Sig. (2-tailed)	.043

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

Appendix N: main study Quantitative results

Table N1: Quantitative data collected from all of the participants taking part in CAPE V2 sessions

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
1	9	6	6	11	0	3	43	78
2	32	16	9	24	9	5	56	63
3	44	19	10	39	36	14	60	44
4	38	13	19	34	15	1	54	68
5	33	9	20	38	10	3	53	75
6	39	5	4	20	15	15	81	40

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
7	55	2	12	56	7	5	80	82
8	53	0	0	42	7	0	100	85
9	69	0	0	51	10	0	100	83
10	69	0	0	61	7	0	100	89
11	88	0	0	65	16	7	100	73
12	67	0	0	56	10	0	100	85

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
13	72	0	0	49	11	3	100	78
14	63	0	0	48	11	7	100	73
15	80	0	0	61	23	3	100	70
16	71	0	0	53	17	3	100	73

Table N2: Quantitative data collected from Jack's CAPE V2 sessions

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
1	1	1	1	3	0	0	33	100
2	10	3	2	10	0	0	67	100
3	13	2	1	12	1	0	81	92
4	5	1	0	5	0	0	83	100
5	9	0	0	6	0	3	100	67
6	9	0	0	8	1	0	100	89

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
7	10	0	0	10	0	0	100	100
8	6	0	0	6	0	0	100	100
9	11	0	0	10	1	0	100	91
10	8	0	0	7	1	0	100	88
11	11	0	0	7	3	3	100	54
12	9	0	0	8	0	0	100	100

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
13	9	0	0	7	1	1	100	78
14	11	0	0	11	2	2	100	73
15	7	0	0	6	3	3	100	50
16	7	0	0	7	1	1	100	78

Table N3: Quantitative data collected from Hugh's CAPE V2 sessions

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
1	5	2	2	5	0	0	56	100
2	6	3	4	4	2	0	46	67
3	9	4	3	5	3	1	56	56
4	9	2	2	5	3	1	69	56
5	6	0	3	3	5	0	67	38
6	6	0	0	1	4	1	100	17

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
7	9	0	0	9	0	0	100	100
8	8	0	0	8	0	0	100	100
9	15	0	0	15	0	0	100	100
10	20	0	0	20	0	0	100	100
11	15	0	0	15	0	0	100	100
12	14	0	0	14	0	0	100	100

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
13	8	0	0	8	0	0	100	100
14	11	0	0	7	3	0	100	70
15	26	0	0	17	9	0	100	65
16	12	0	0	9	3	0	100	75

Table N4: Quantitative data collected from Bill's CAPE V2 sessions

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol	Percentage of correct symbol tidy	Percentage of correct symbol
1	1	1	2	1	0	2	25	33
2	9	4	0	4	4	1	69	44
3	9	3	0	6	0	3	75	67
4	7	2	0	7	0	0	78	100
5	4	2	6	10	0	0	33	100
6	14	1	0	6	8	0	93	43

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
7	14	0	1	9	5	1	93	60
8	11	0	0	8	3	0	100	73
9	13	0	0	8	5	0	100	62
10	13	0	0	10	3	0	100	77
11	24	0	0	15	9	0	100	63
12	16	0	0	6	10	0	100	38

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
13	15	0	0	11	4	0	100	73
14	14	0	0	12	1	1	100	86
15	25	0	0	17	8	0	100	68
16	21	0	0	13	8	0	100	62

Table N5: Quantitative data collected from Tim's CAPE V2 sessions

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
1	2	2	1	2	0	1	40	67
2	6	4	0	3	1	2	60	50
3	4	6	2	5	0	7	33	42
4	7	5	12	10	10	0	29	50
5	3	4	8	8	3	0	20	73
6	8	3	0	3	1	4	73	38

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
7	6	2	9	9	2	4	35	60
8	10	0	0	7	3	0	100	70
9	10	0	0	6	4	0	100	60
10	9	0	0	6	3	0	100	67
11	16	0	0	8	4	4	100	50
12	0	0	0	0	0	0	0	0

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
13	11	0	0	7	4	0	100	64
14	15	0	0	7	5	3	100	47
15	8	0	0	5	3	0	100	63
16	15	0	0	9	4	2	100	60

Table N6: Quantitative data collected from Molly's CAPE V2 sessions

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
1	0	0	0	0	0	0	0	0
2	1	2	3	3	2	2	17	43
3	9	4	4	11	32	3	53	24
4	10	3	5	7	2	0	56	78
5	11	3	3	11	2	0	65	85
6	2	1	4	2	1	10	29	15

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
7	16	0	2	19	0	0	89	100
8	18	0	0	13	1	0	100	93
9	20	0	0	12	0	0	100	100
10	19	0	0	18	0	0	100	100
11	22	0	0	20	0	0	100	100
12	28	0	0	28	0	0	100	100

Session number	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy	Correct symbol selections	Incorrect symbol selections	Teacher prompted symbol selections	Percentage of correct symbol tidy	Percentage of correct symbol selection
13	29	0	0	16	2	2	100	80
14	12	0	0	11	0	1	100	92
15	14	0	0	16	0	0	100	100
16	16	0	0	15	1	0	100	94

Study population quantitative results

Table N7: association between sessions and symbol tidy responses in response to virtual tutor requests for all participants

	Session	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy
Spearman's rho Session Correlation Coefficient	1.000	.870**	-.745**	-.674*
Sig. (1-tailed)	.	.000	.000	.002
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Table N8: Correlation between sessions and picture selection for all participants

	Session	Correct Picture	Incorrect picture selected	Teacher prompted picture selection
Spearman's rho Session Correlation Coefficient	1.000	.733**	.82	-.170
Sig. (1-tailed)	.	.000	0.366	.026
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).
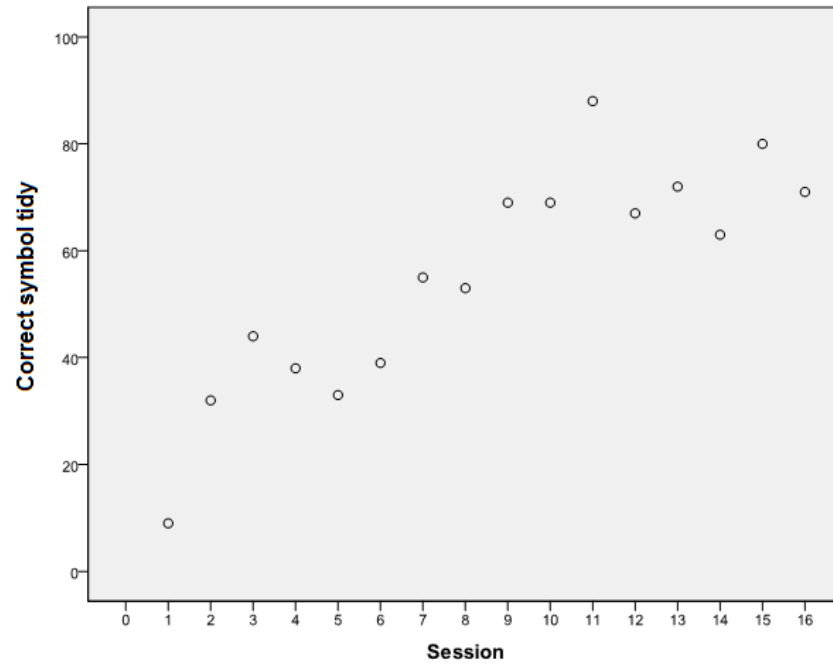
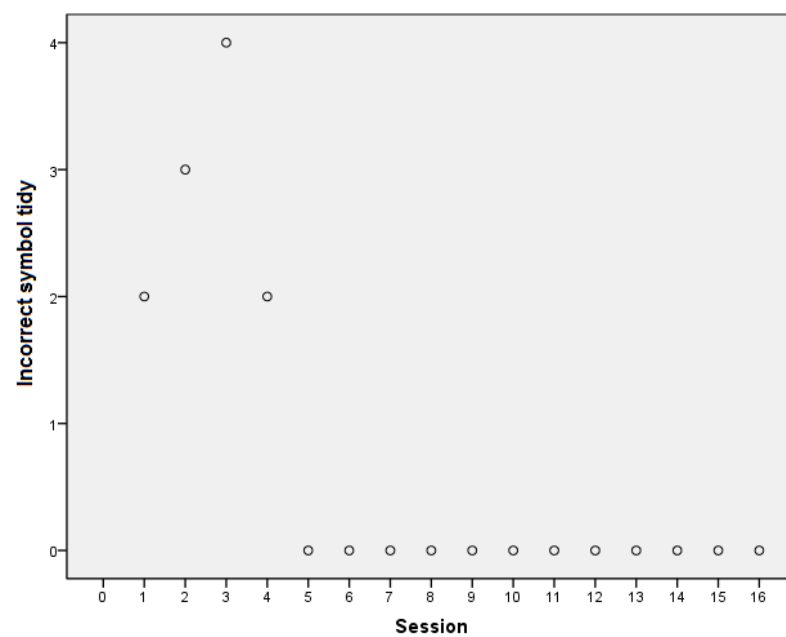Figure N1: frequency of correct symbol tidy responses to virtual tutor requests by all participants over sessions
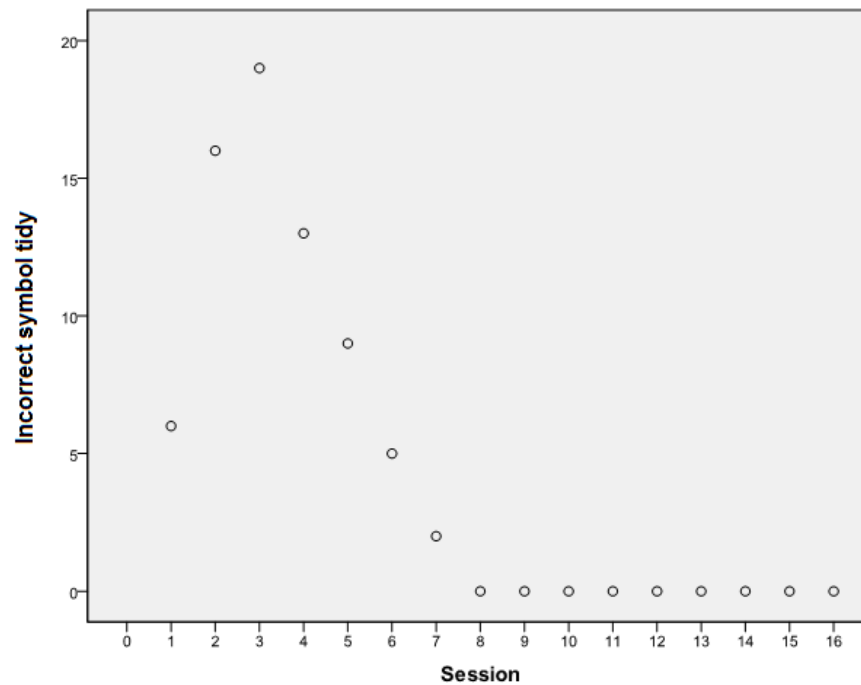
Figure N2: frequency of incorrect symbol tidy responses to virtual tutor requests by all participants over sessions
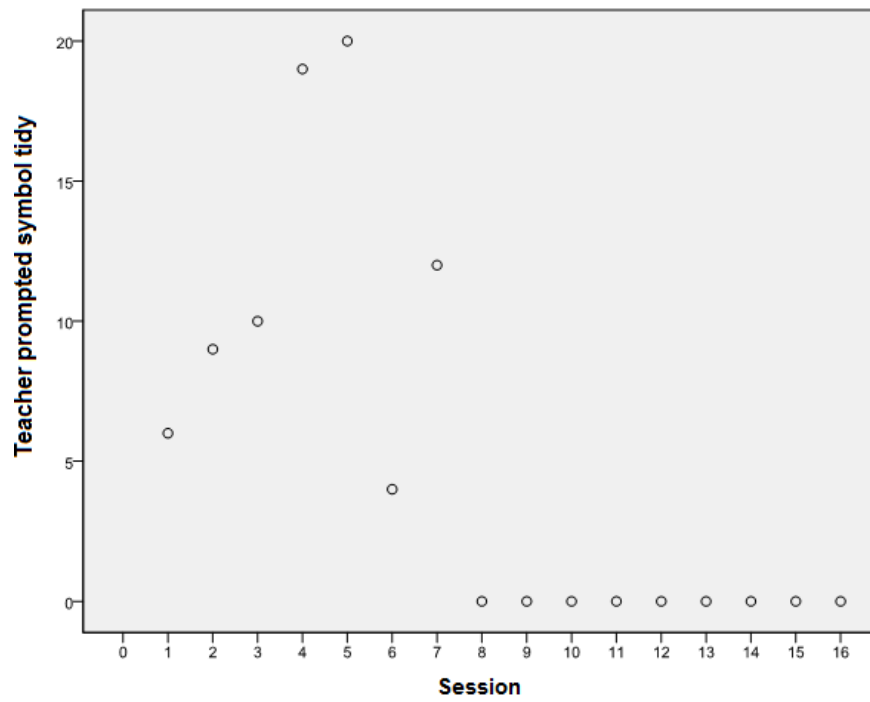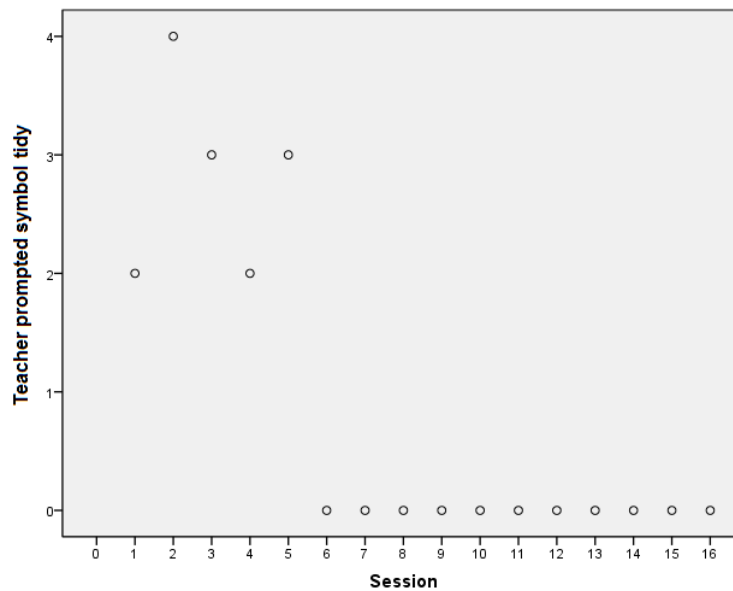
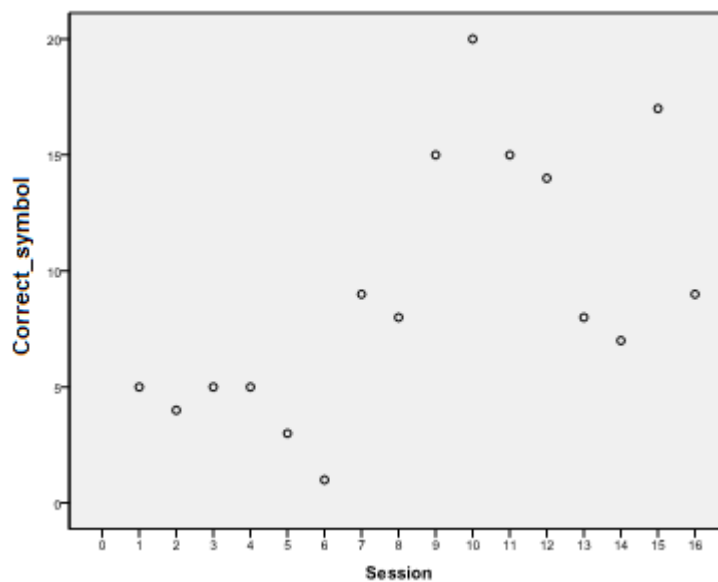Figure N3: frequency of teacher prompted symbol tidy responses to virtual tutor requests by all participants over sessions
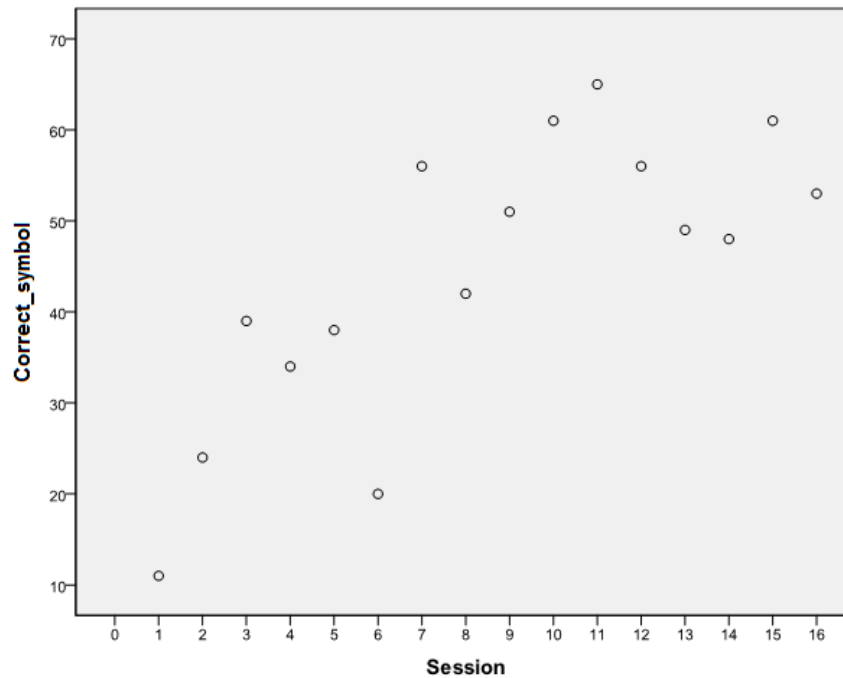
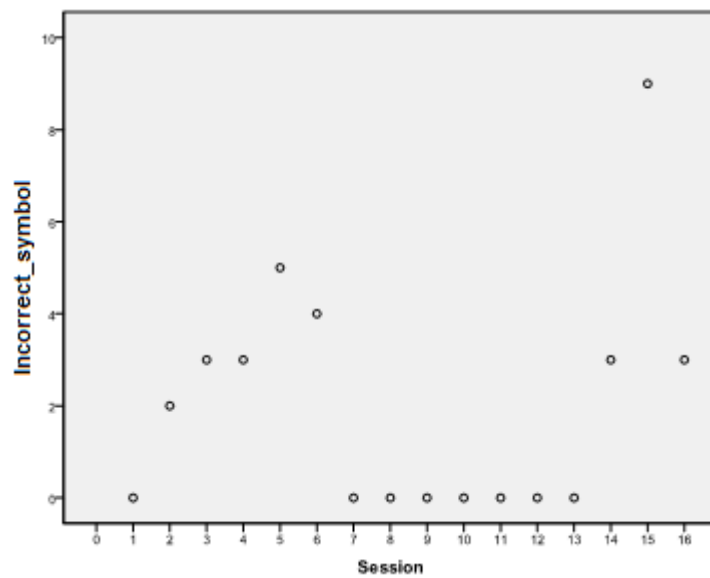Figure N4: frequency of correct symbols selected by all participants over sessions
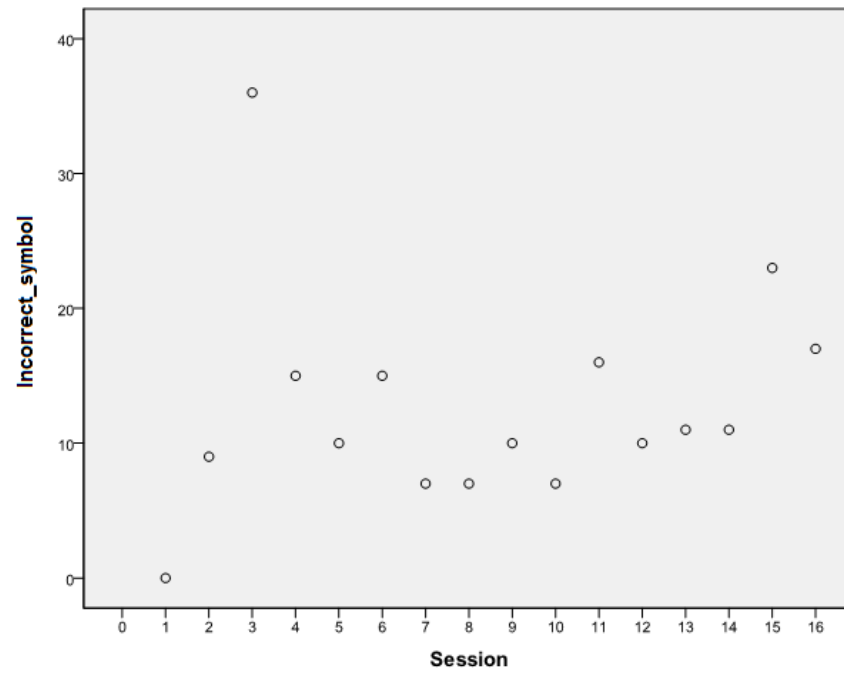
Figure N5: frequency of incorrect symbols selected by all participants over sessions
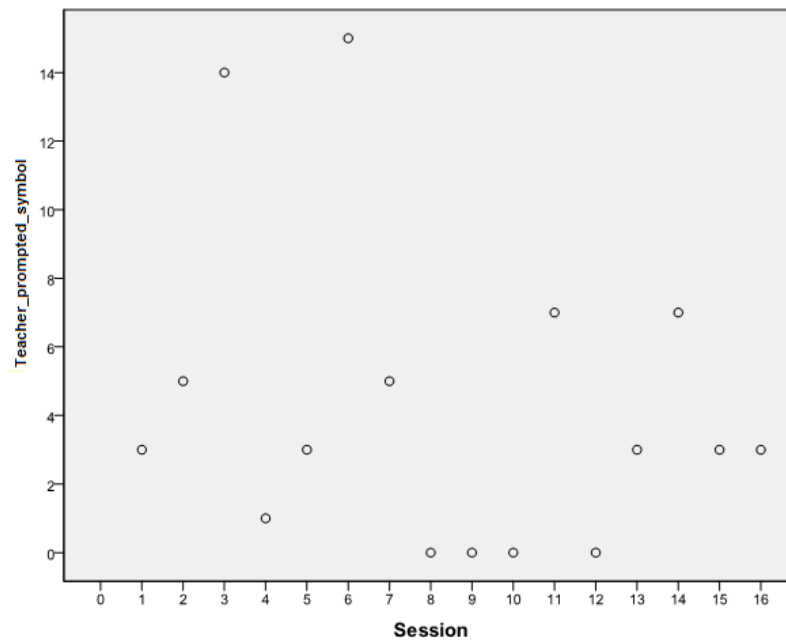
Figure N6: frequency of teacher prompted picture selection by all participants over sessions
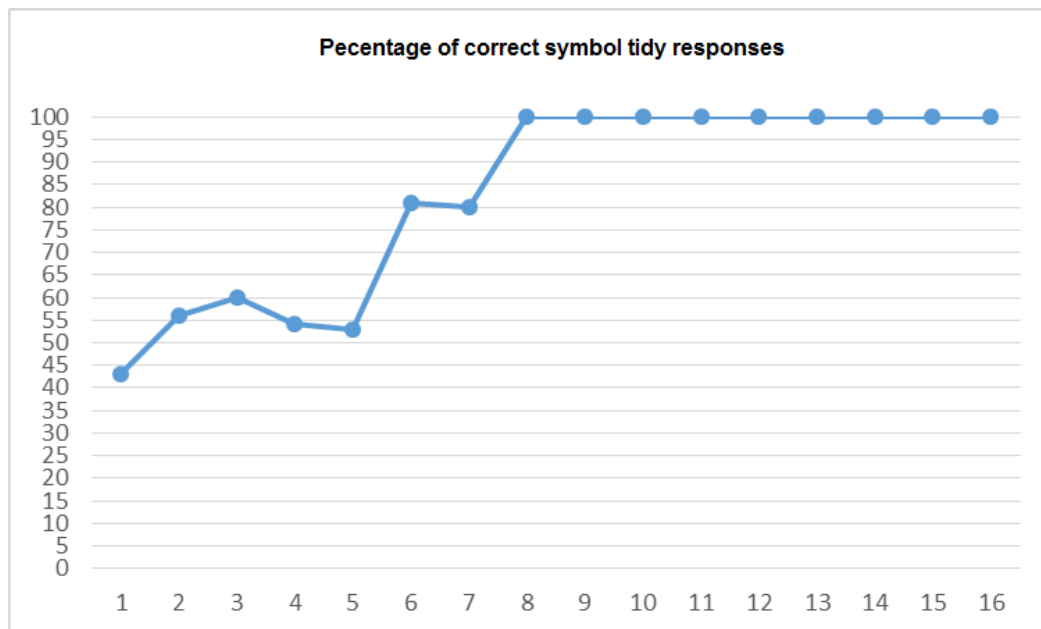
Figure N7: percentage of correct symbol tidy responses for all participants over sessions
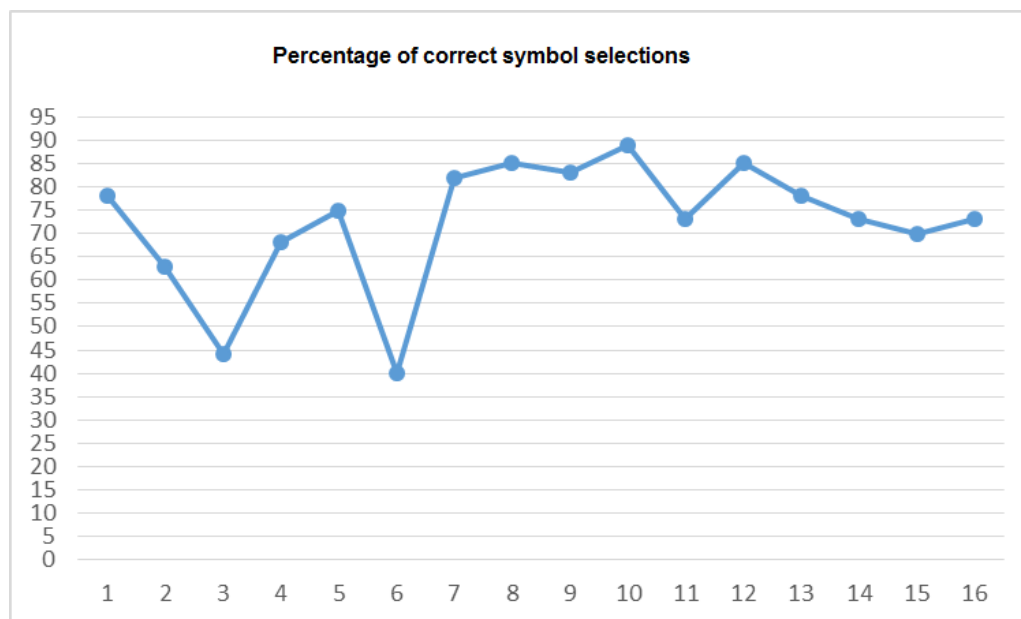
Figure N8: percentage of correct symbol selections for all participants over sessions

388

Jack

Table N9: association between sessions and symbol tidy responses to virtual tutor requests (Jack)

	Session	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy
Spearman's rho Session Correlation Coefficient	1.000	.030	-.745**	-.674**
Sig. (1-tailed)	.	.456	.000	.002
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Table N10: Correlation between sessions and picture selection (Jack)

	Session	Correct Picture	Incorrect picture selected	Teacher prompted picture selection
Spearman's rho Session Correlation Coefficient	1.000	.063	.298	-.562*
Sig. (1-tailed)	.	.409	0.131	.012
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).
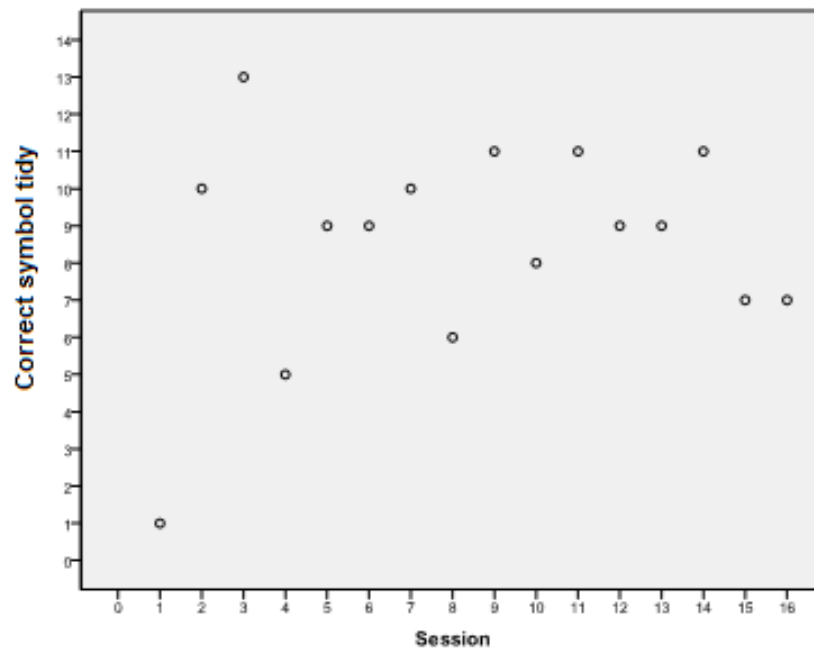
Figure N9: frequency of correct symbol tidy responses to virtual tutor requests by Jack over sessions
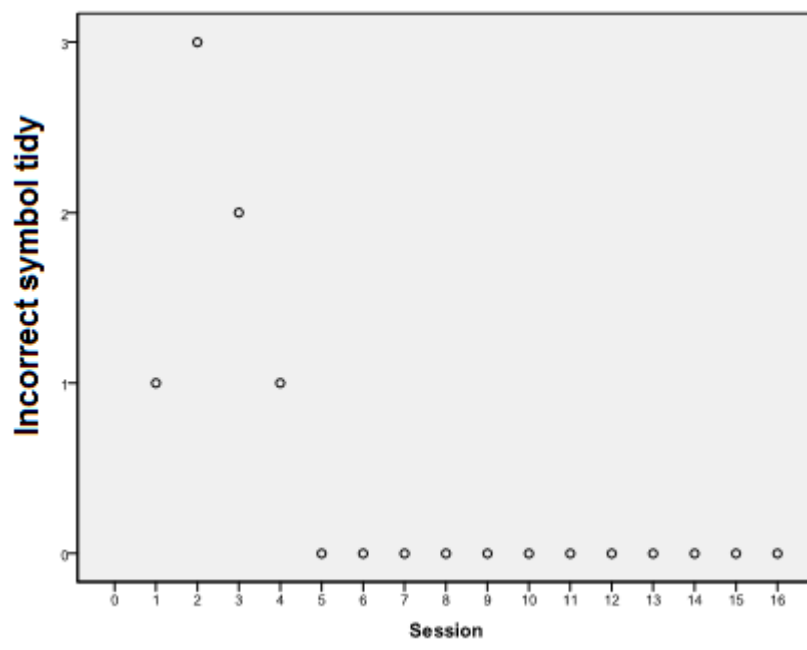
Figure N10: frequency of incorrect symbol tidy responses to virtual tutor requests by Jack over sessions
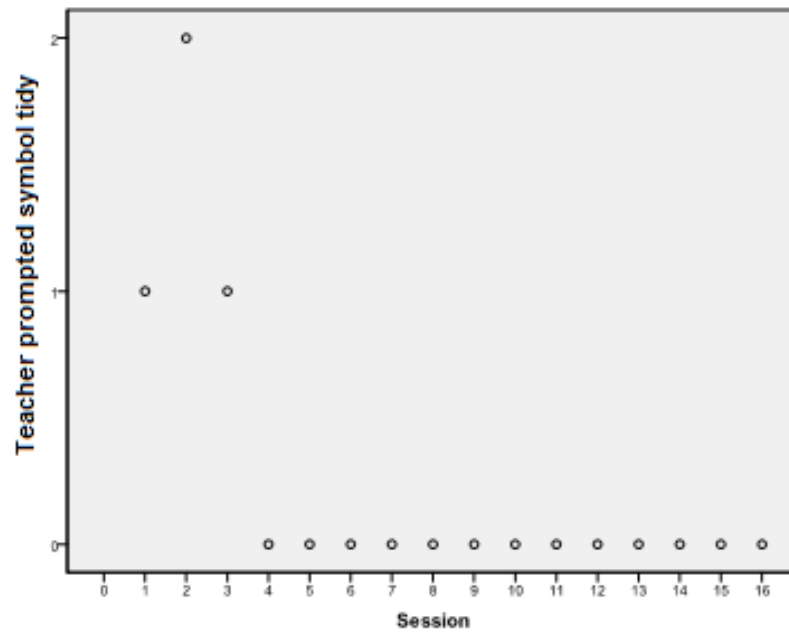
Figure N11: frequency of teacher prompted symbol tidy responses to virtual tutor requests by Jack over sessions
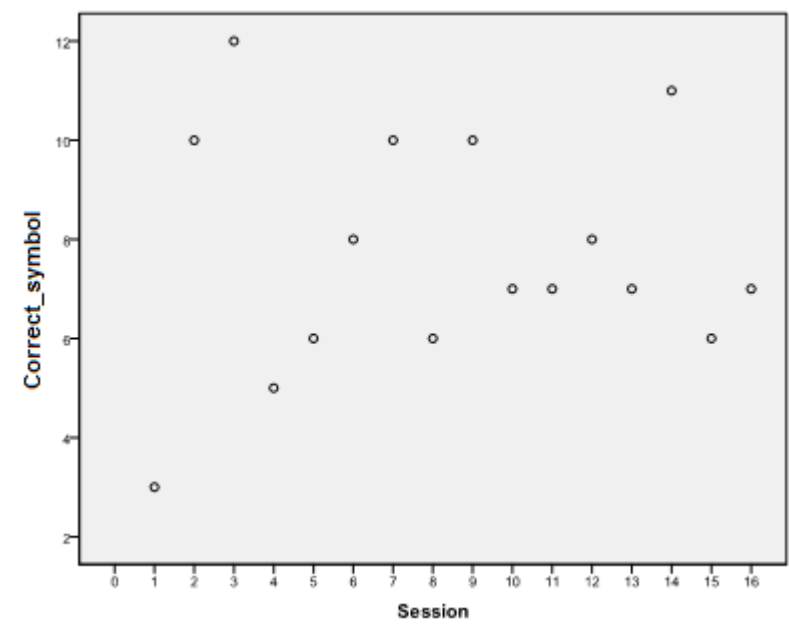
Figure N12: frequency of correct symbols selected by Jack over sessions
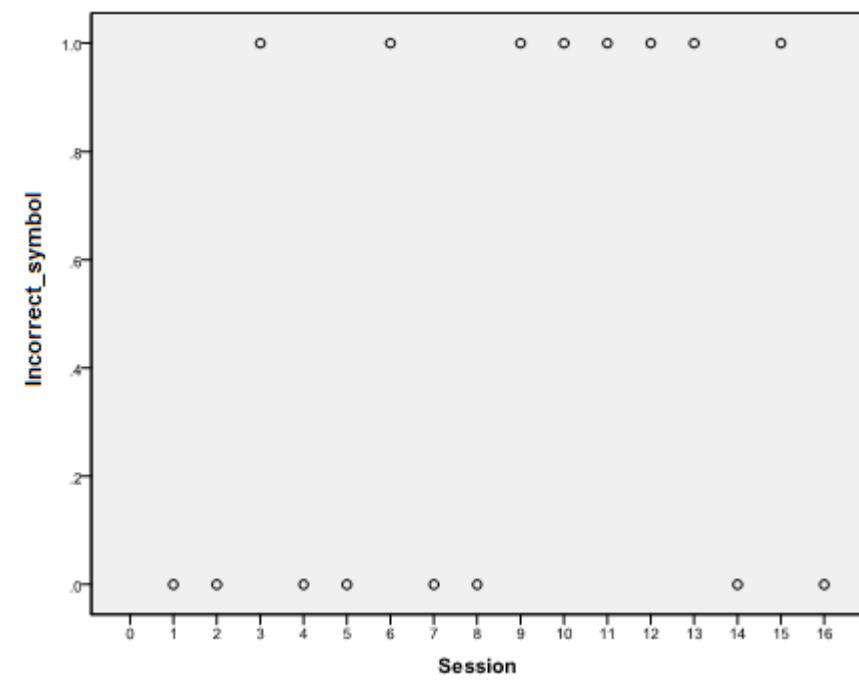
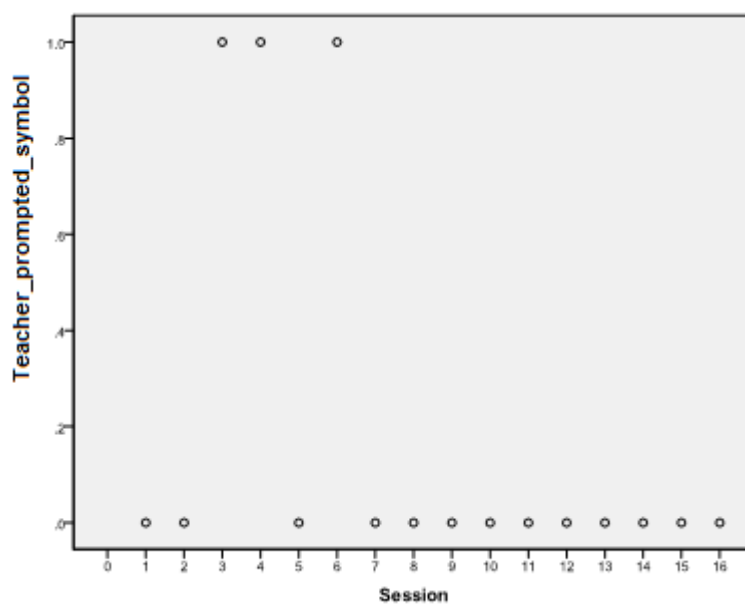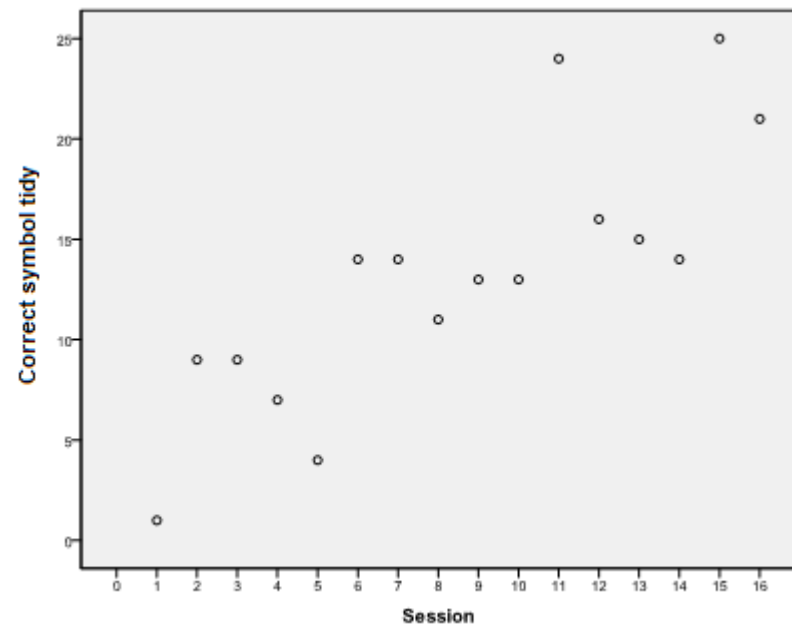Figure N13: frequency of incorrect symbols selected by Jack over sessions
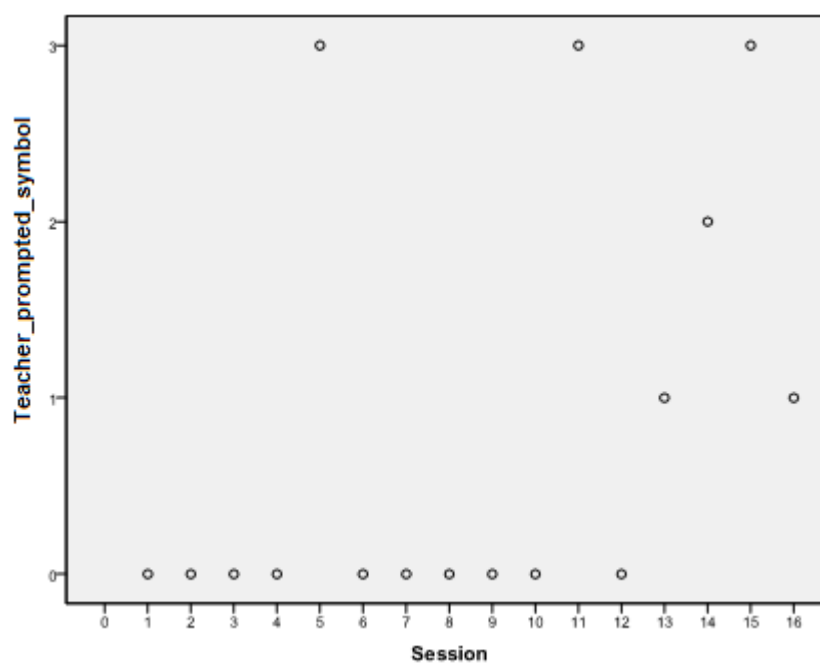
Figure N14: frequency of teacher prompted picture selection by Jack over sessions
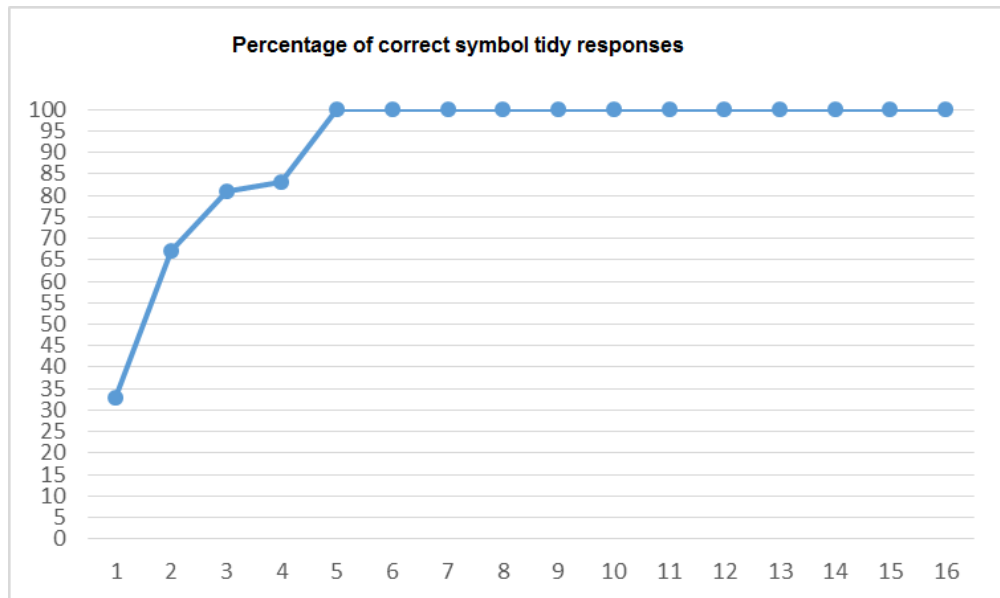
Figure N15: percentage of correct symbol tidy responses by Jack over sessions
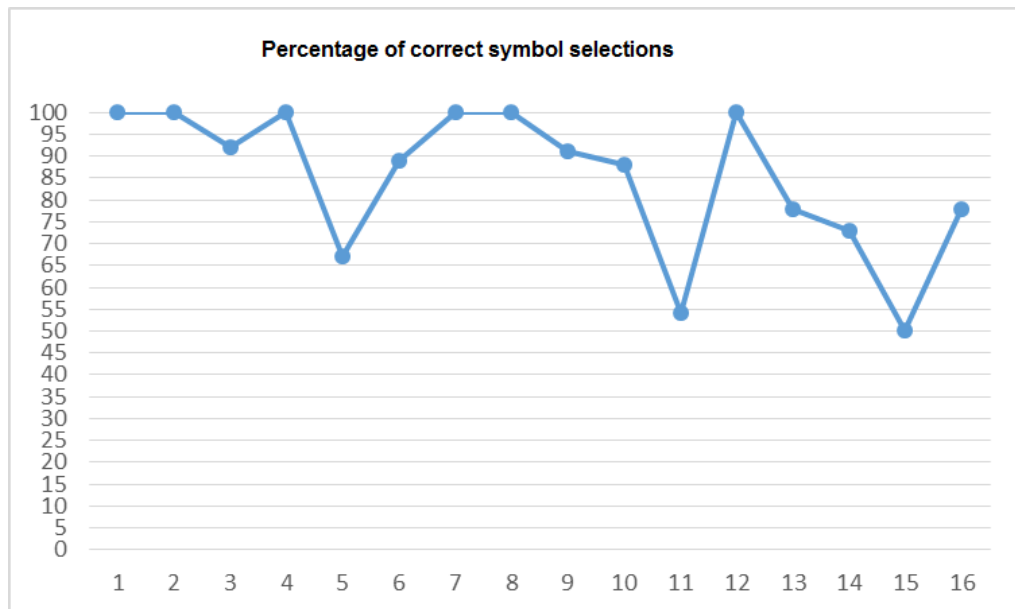
Figure N16: percentage of correct symbol selections by Jack over sessions

Hugh

Table N11: association between sessions and symbol tidy responses to virtual
tutor requests

	Session	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy
Spearman's rho Session Correlation Coefficient	1.000	.686**	-.741**	-.787**
Sig. (1-tailed)	.	.002	.001	.000
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Table N12: association between sessions and picture selection

	Session	Correct picture	Incorrect picture selected	Teacher prompted Picture
Spearman's rho Session Correlation Coefficient	1.000	.659**	.019	-.434*
Sig. (1-tailed)	.	.003	.472	.046
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).
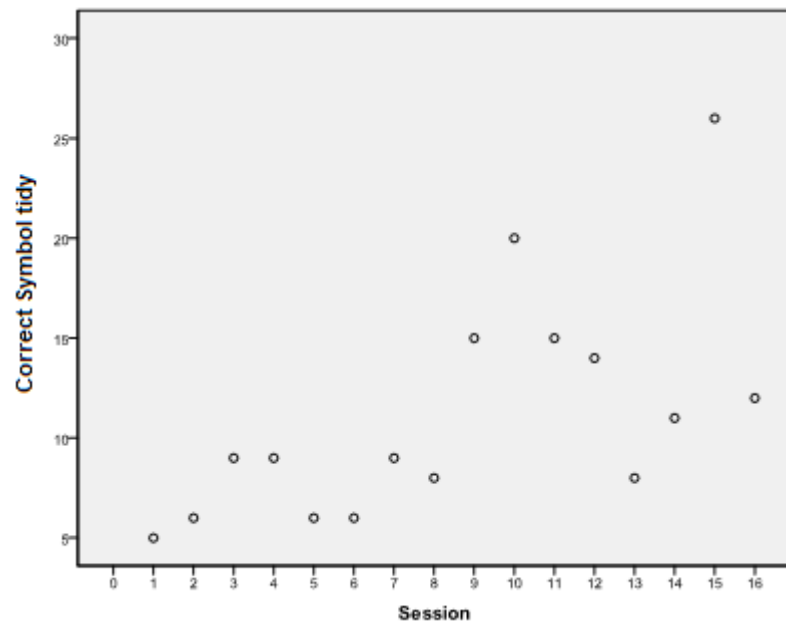
Figure N17: frequency of correct symbol tidy responses to virtual tutor requests by Hugh over sessions
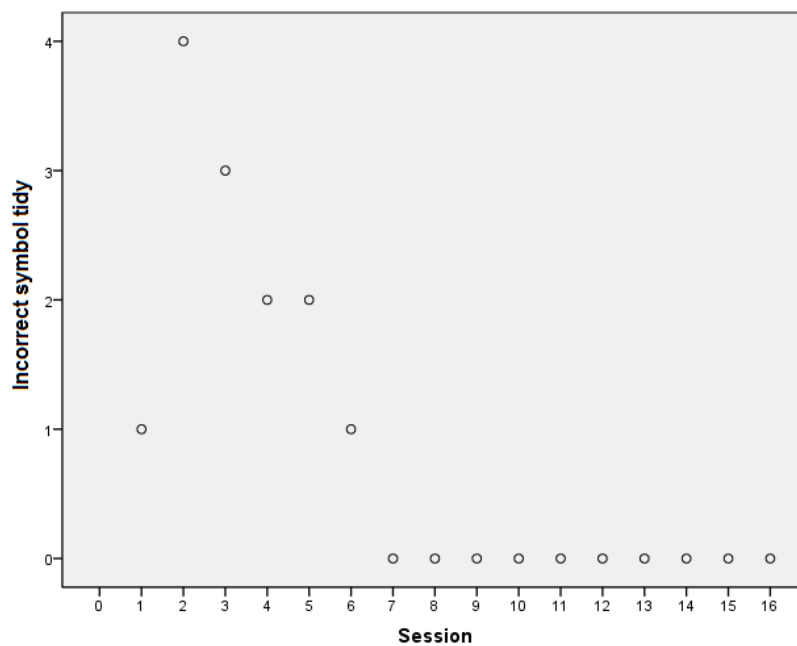

Figure N18: frequency of incorrect symbol tidy responses to virtual tutor requests by Hugh over sessions
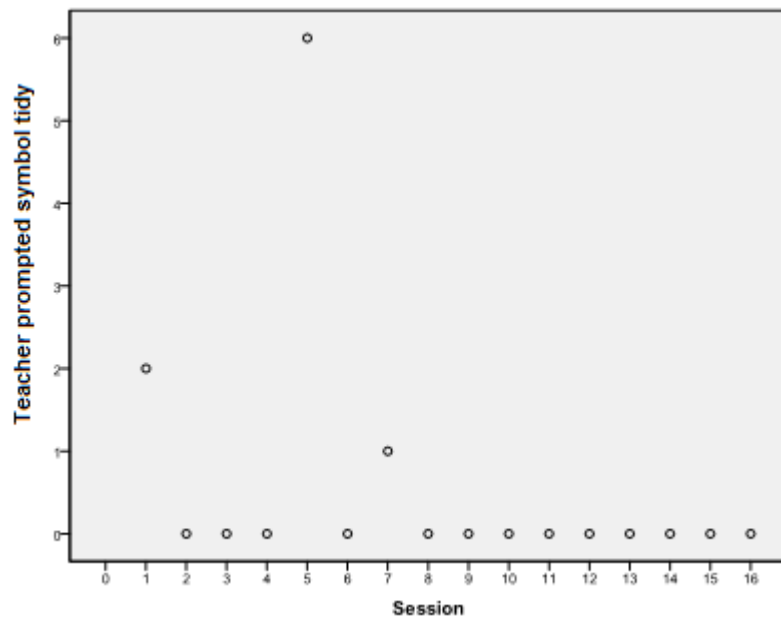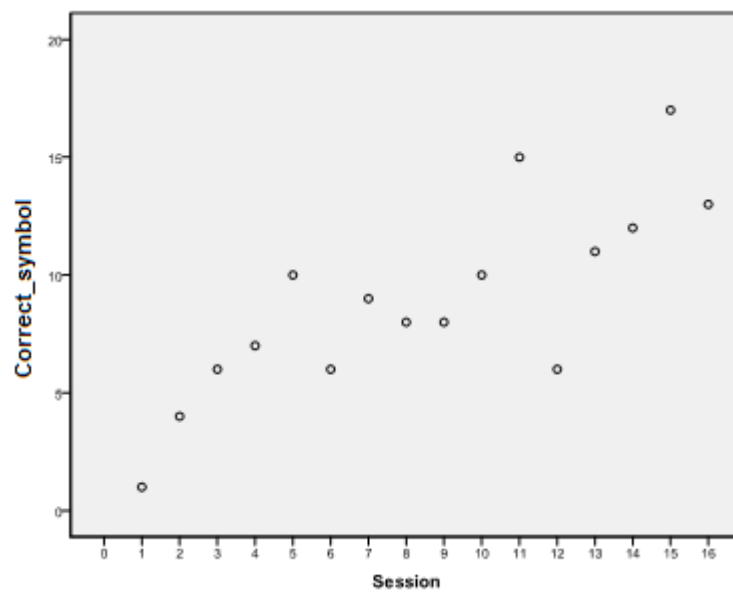
395

Figure N19: frequency of teacher prompted symbol tidy responses to virtual tutor requests by Hugh over sessions

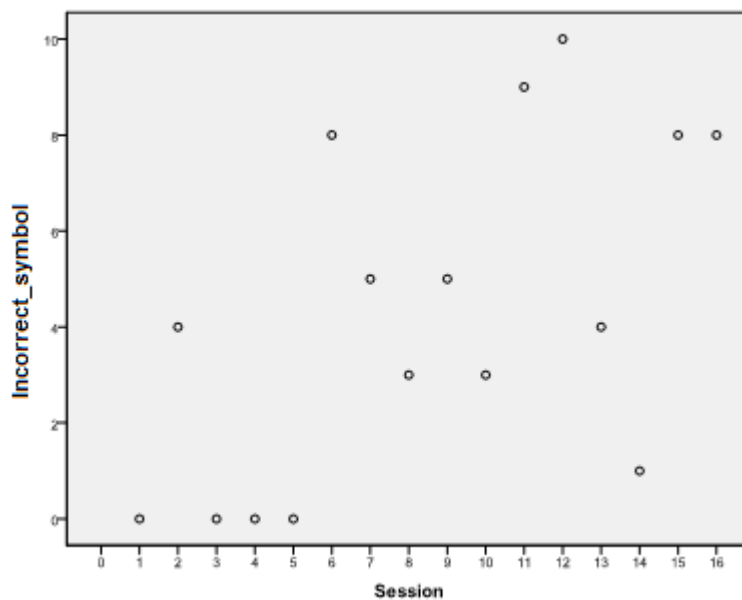Figure N20: frequency of correct symbols selected by Hugh over sessions

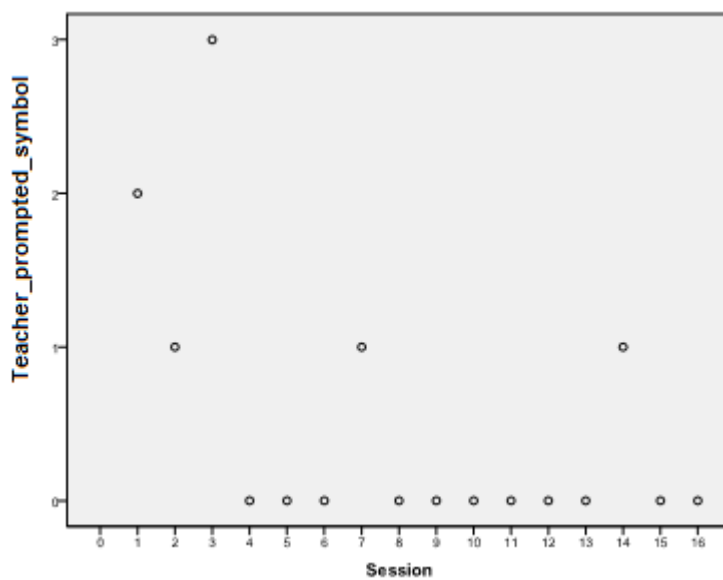Figure N21: frequency of incorrect symbols selected by Hugh over sessions

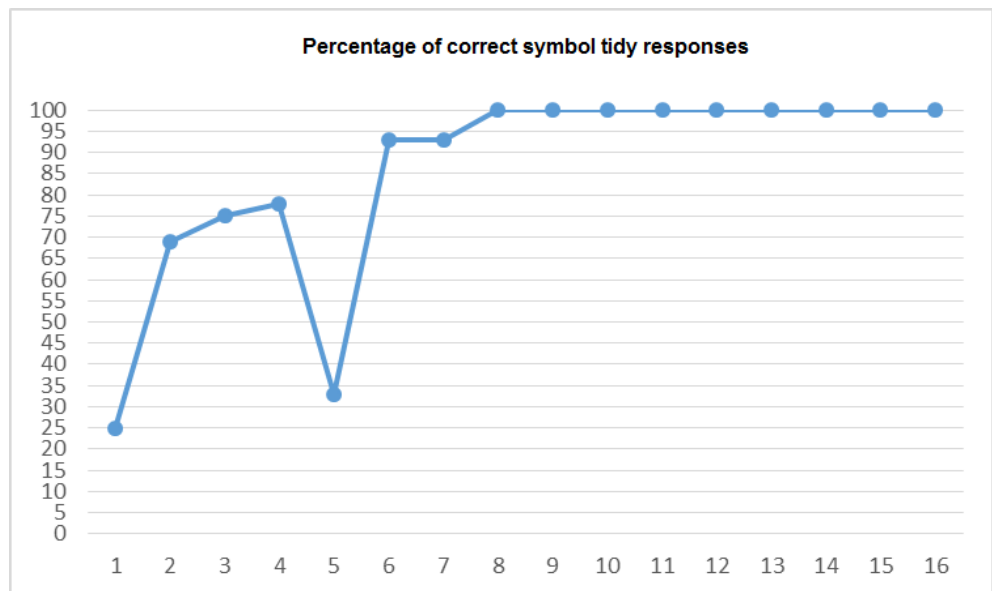Figure N22: frequency of teacher prompted symbols selected by Hugh over sessions
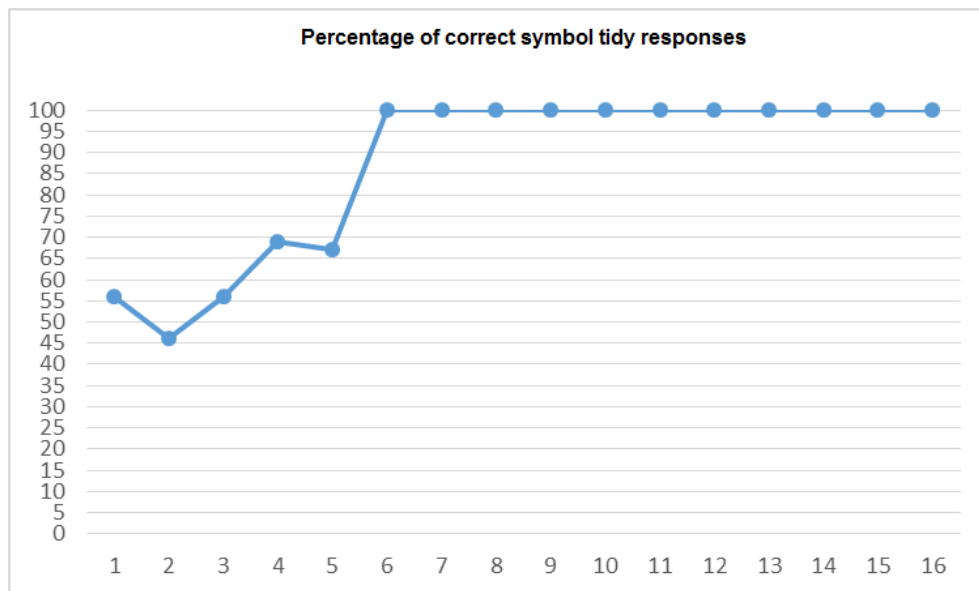
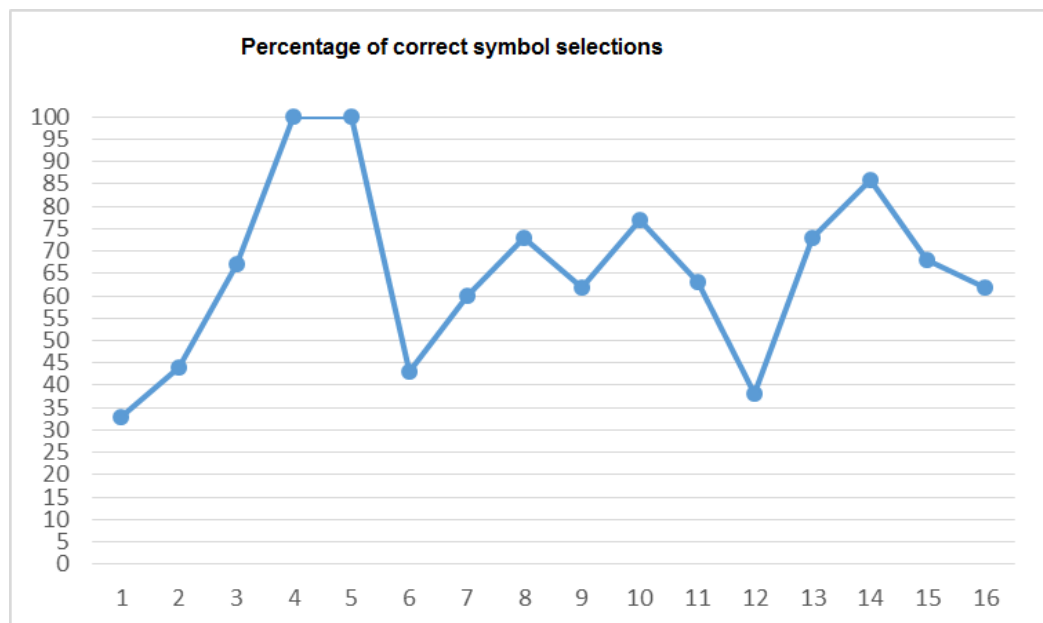Figure N23: percentage of correct symbol tidy responses by Hugh over sessions
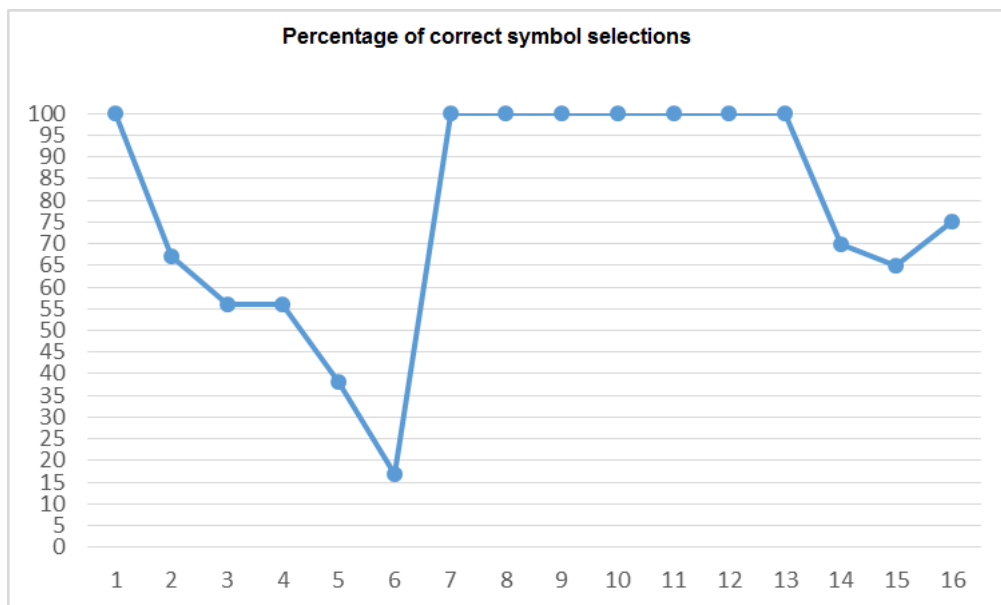
Figure N24: percentage of correct symbol selections by Hugh over sessions

Bill

Table N13: association between sessions responses to virtual tutor requests

	Session	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy
Spearman's rho Session Correlation Coefficient	1.000	.824**	-.828**	-.440*
Sig. (1-tailed)	.	.000	.000	.044
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Table N14: association between sessions and picture selection

	Session	Correct Picture	Incorrect picture selected	Teacher prompted picture selection
Spearman's rho Session Correlation Coefficient	1.000	.804**	.587**	-.503*
Sig. (1-tailed)	.	.000	.008	.024
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

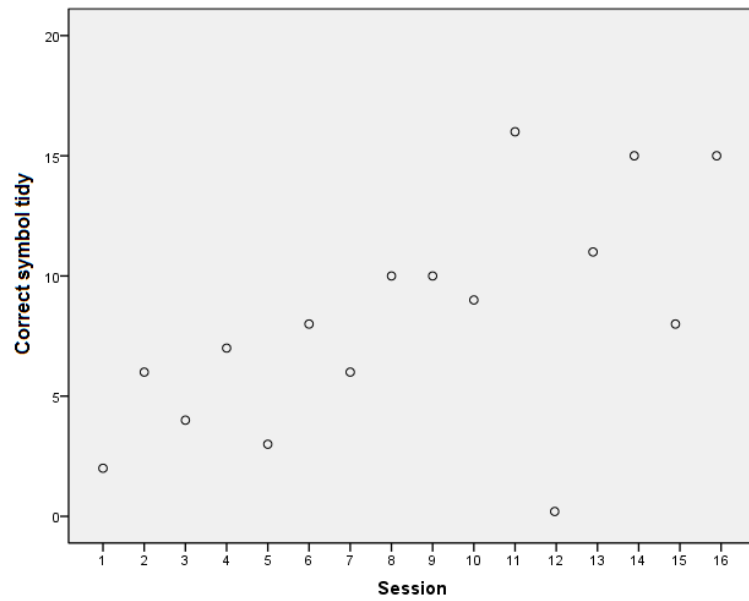**. Correlation is significant at the 0.01 level (1-tailed).

Figure N25: frequency of correct symbol tidy responses to virtual tutor requests by Bill over sessions
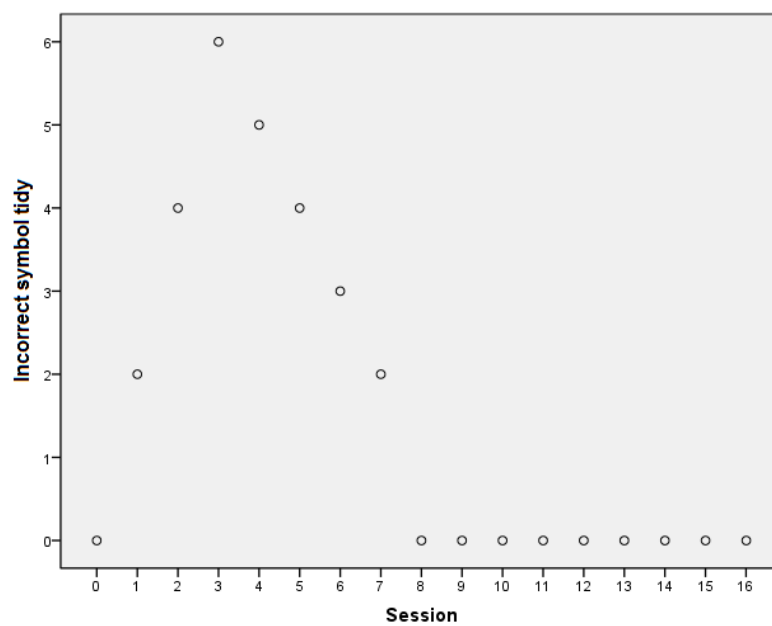

Figure N26: frequency of incorrect symbol tidy responses to virtual tutor requests by Bill over sessions
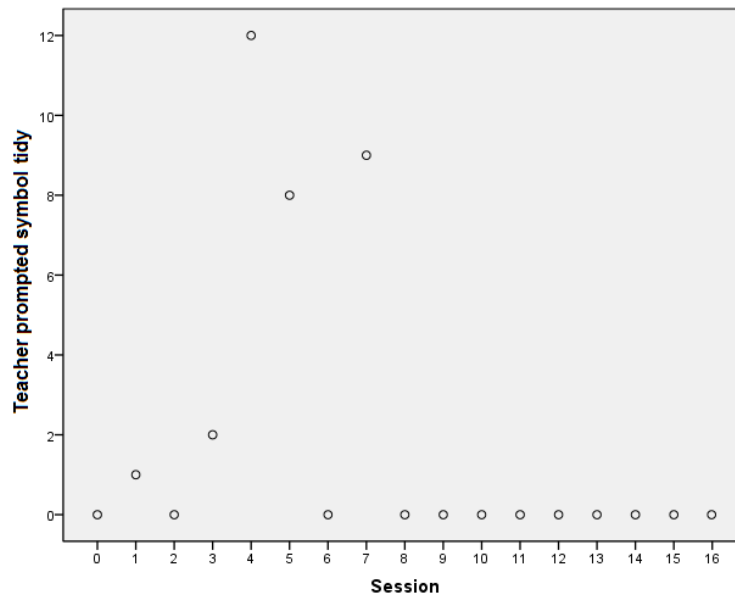
400

Figure N27: frequency of teacher prompted symbol tidy responses to virtual tutor requests by Bill over sessions

Figure N28: frequency of correct symbols selected by Bill over sessions

Figure N29: frequency of incorrect symbols selected by Bill over sessions

Figure N30: frequency of teacher prompted symbols selected by Bill over sessions

Figure N31: percentage of correct symbol tidy responses by Bill over sessions

Figure N32: percentage of correct symbol selections by Bill over sessions

Tim

Table N15: Correlation between sessions and symbol tidy responses to virtual
tutor requests

	Session	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy
Spearman's rho Session Correlation Coefficient	1.000	.855**	-.654**	-.465*
Sig. (1-tailed)	.	.000	.003	.035
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Table N16: association between sessions and picture selection

	Session	Correct Picture	Incorrect picture selected	Teacher prompted picture selection
Spearman's rho Session Correlation Coefficient	1.000	.471*	-.680**	-.043
Sig. (1-tailed)	.	.033	.002	.438
N	16	16	16	16

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Figure N33: frequency of correct symbol tidy responses to virtual tutor requests by Tim over sessions

Figure N34: frequency of incorrect symbol tidy responses to virtual tutor requests by Tim over sessions

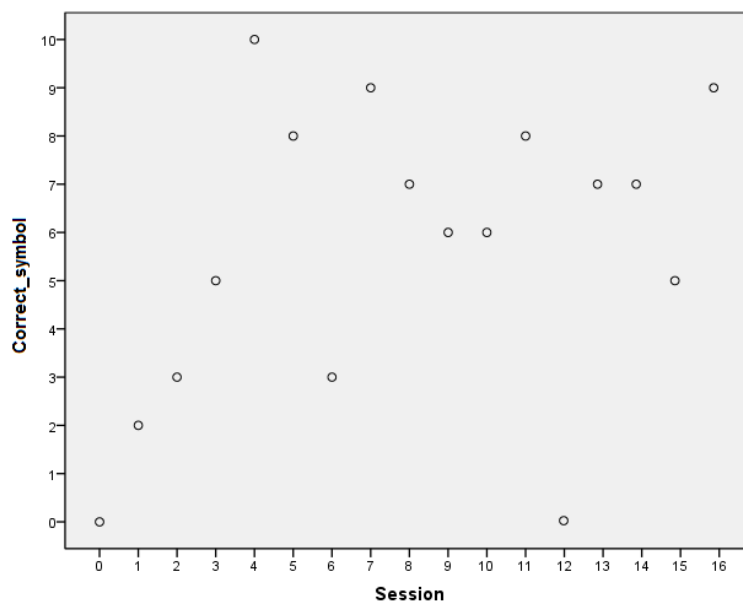Figure N35: frequency of teacher prompted symbol tidy responses to virtual tutor requests by Tim over sessions

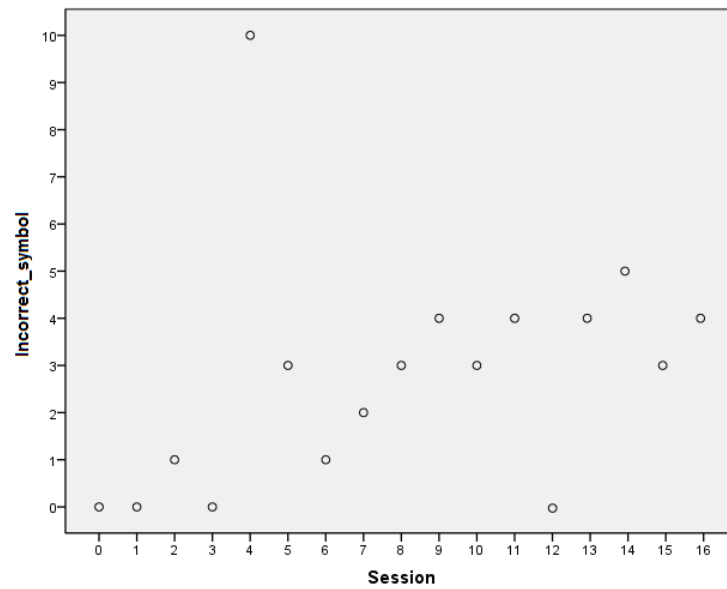Figure N36: frequency of correct symbols selected by Tim over sessions

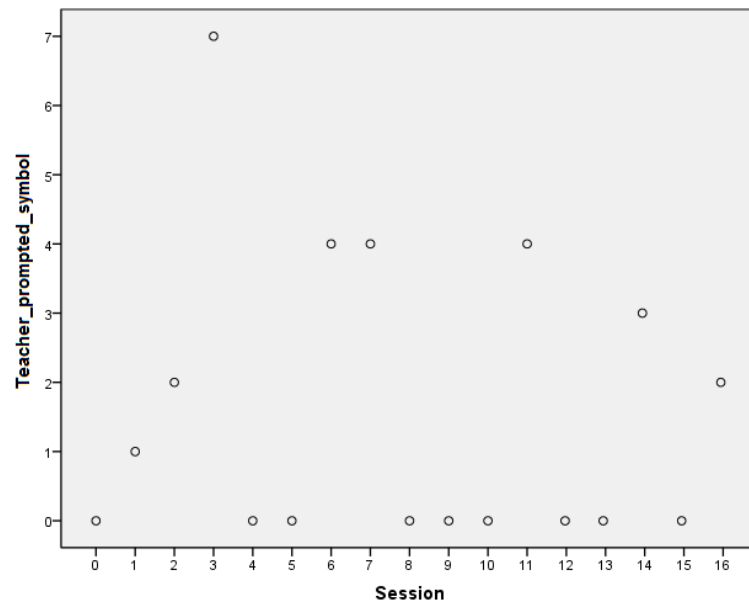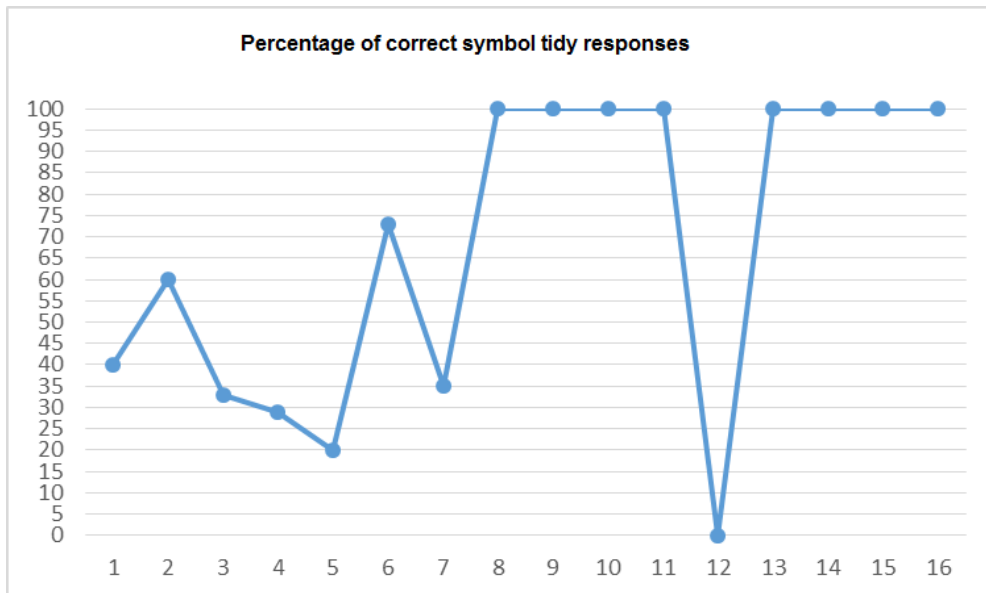Figure N37: frequency of incorrect symbols selected by Tim over sessions

Figure N38: frequency of teacher prompted symbols selected by Tim over sessions

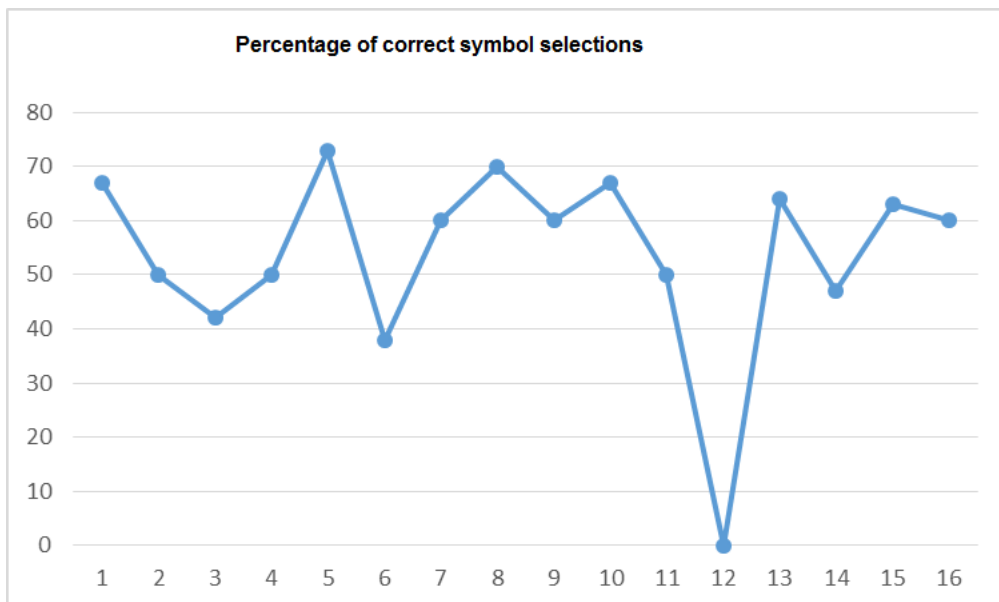Figure N39: percentage of correct symbol tidy responses by Tim over sessions

Figure N40: percentage of correct symbol selections by Tim over sessions

Molly

Table N17: association between sessions and symbol tidy responses to virtual
tutor requests

	Session	Correct symbol tidy	Incorrect symbol tidy	Teacher prompted symbol tidy
Spearman's rho Session Correlation Coefficient	1.000	.321	-.813**	-.655**
Sig. (1-tailed)	.	.121	.000	.004
N	15	15	15	15

*. Correlation is significant at the 0.05 level (1-tailed).

**. Correlation is significant at the 0.01 level (1-tailed).

Table N18: association between sessions and picture selection

	Session	Correct Picture	Incorrect picture selected	Teacher prompted picture selection
Spearman's rho Session Correlation Coefficient	1.000	.581*	-.584*	-.311
Sig. (1-tailed)	.	.012	.011	.130
N	15	15	15	15

*. Correlation is significant at the 0.05 level (1-tailed).

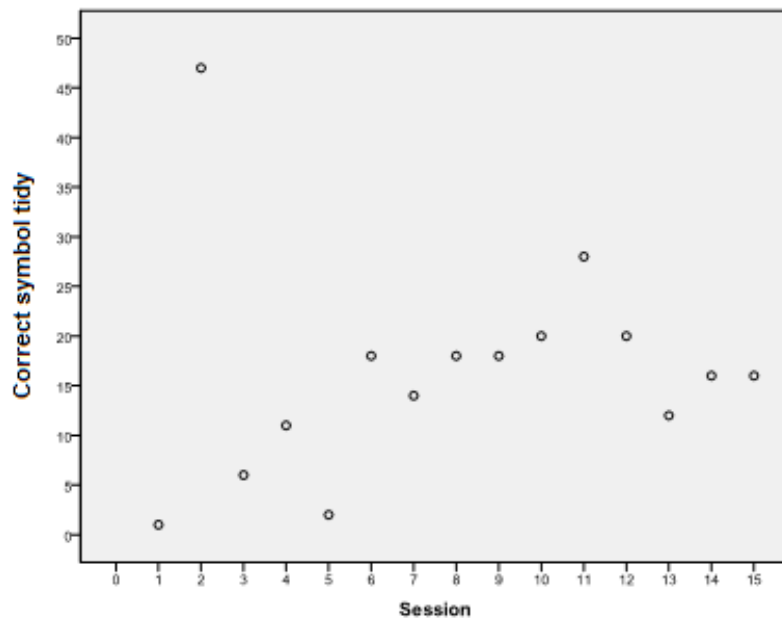**. Correlation is significant at the 0.01 level (1-tailed).

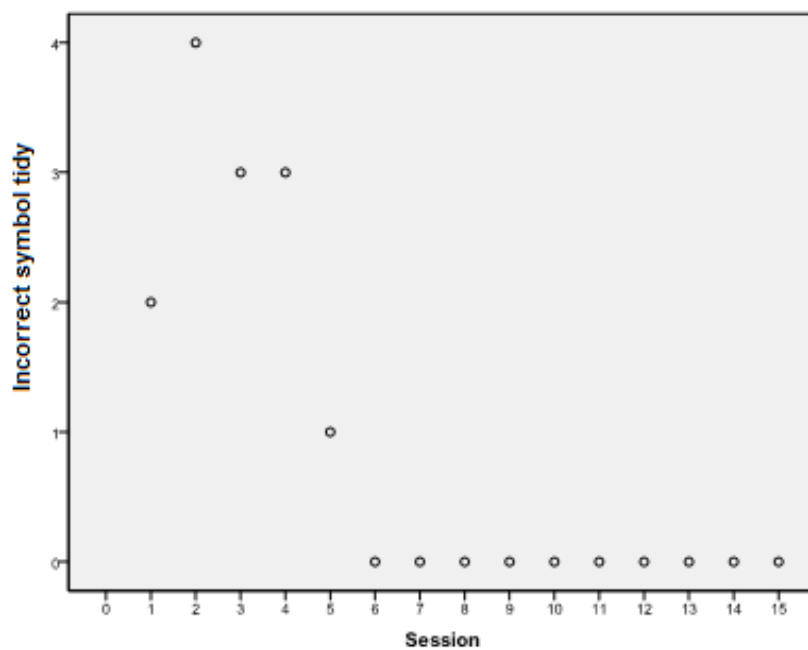Figure N 41: frequency of correct symbol tidy responses to virtual tutor requests by Molly over sessions

Figure N42: frequency of incorrect symbol tidy responses to virtual tutor requests by Molly over sessions
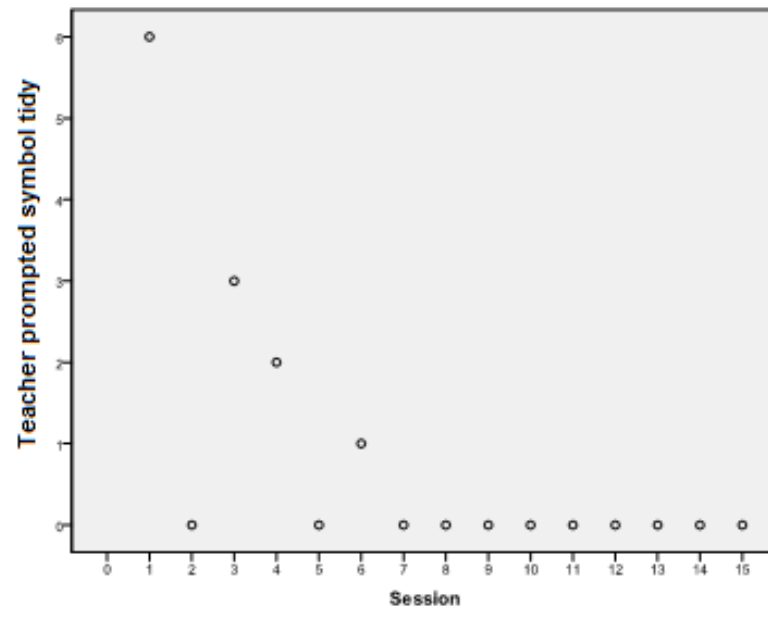
Figure N43: frequency of teacher prompted symbol tidy responses to virtual tutor requests by Molly over sessions
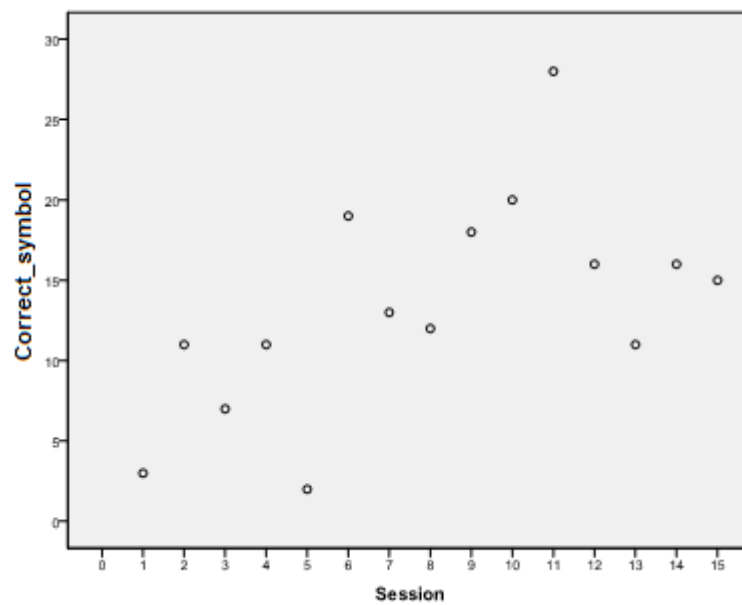

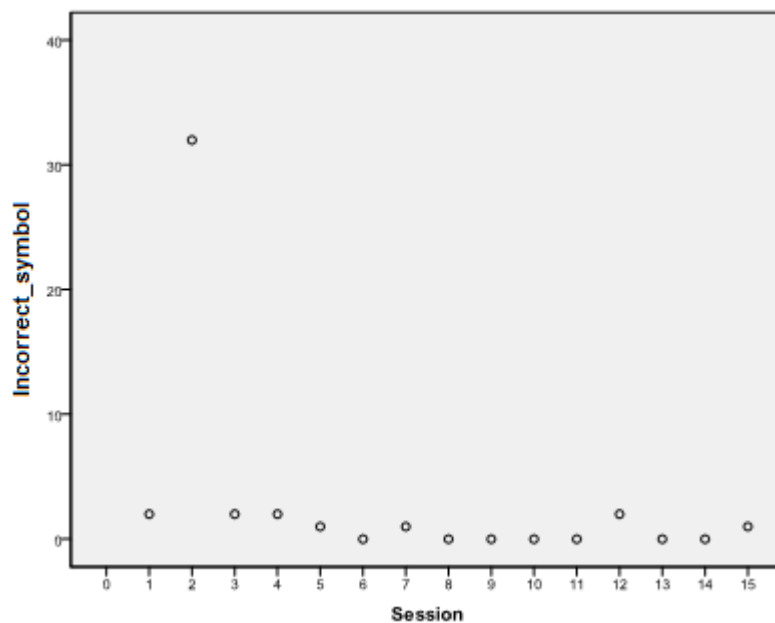Figure N44: frequency of correct symbols selected by Molly over sessions

Figure N45: frequency of incorrect symbols selected by Molly over sessions
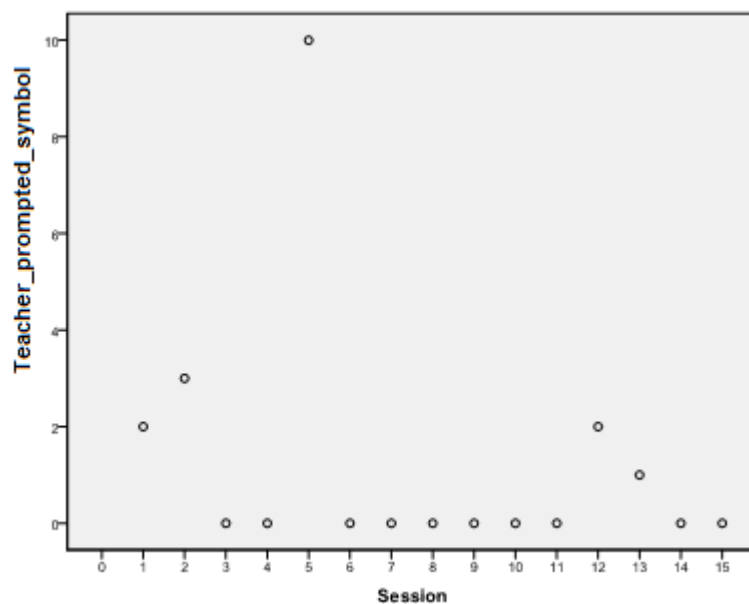

Figure N46: frequency of teacher prompted symbols selected by Molly over sessions
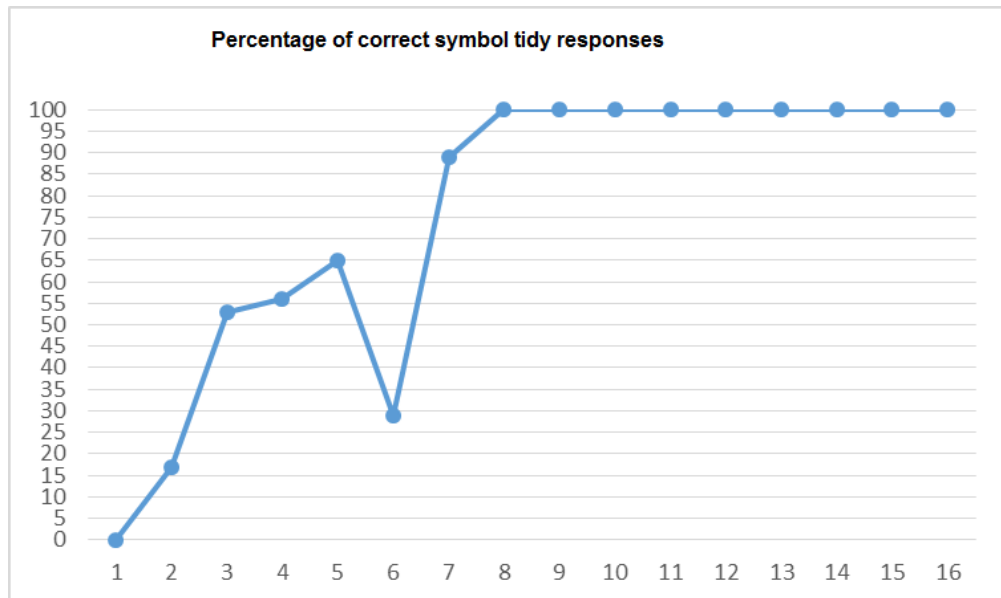
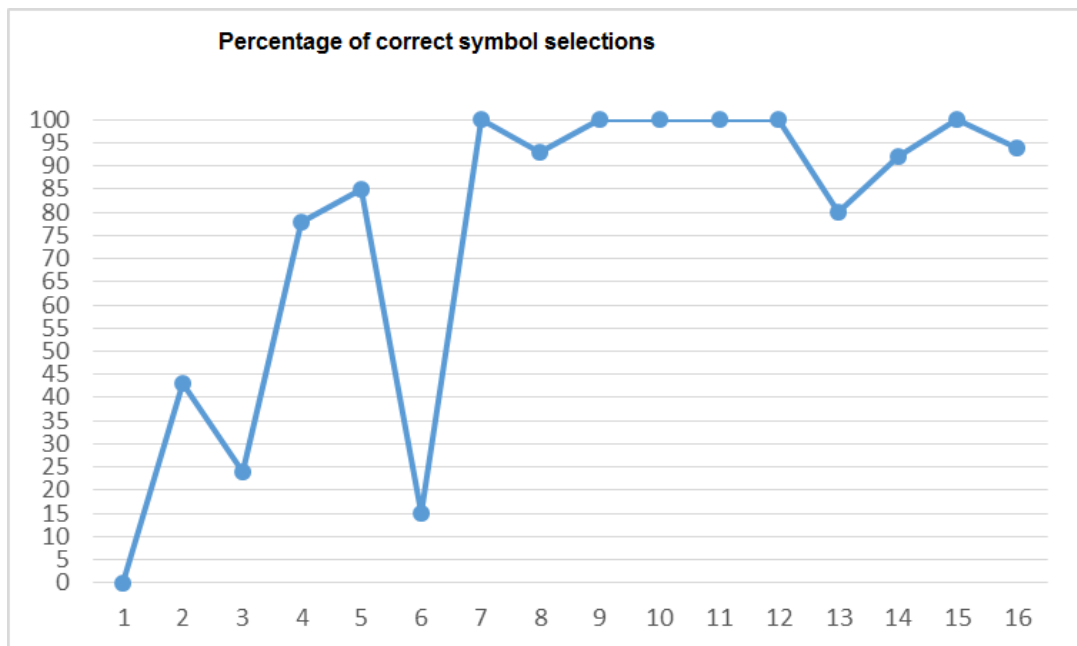Figure N47: percentage of correct symbol tidy responses by Molly over sessions

Figure N48: percentage of correct symbol selections by Molly over sessions

Appendix O – Example of thematic analysis from main study data

O1: Participant [Bill] session transcript and initial coding

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
At the beginning of the session [Bill] smiles and plays with the reader, he is keen to start (6.90)...[Bill] looks at the TA and grins, TA diverts [Bill] attention to the screen (9.25)...during the intro [Bill] smiles and looks at the screen, he is tapping his finger and seems anxious to start the session (15.37)...	
The first task is 2 bananas, [Bill] looks down to the folder and selects 3 (19.12)...TA removes [Bill]s hand from the reader (21.62)...on the wrong clip [Bill] continues to smile and watch VT (23.18)...he watches the output and scratches the back of his neck with this left hand (25.83)...on the tidy [Bill] removes the symbol (28.77)...	Wrong response – wrong symbol Symbol select – symbol tidy
On the 2 banana repeat TA prompts [Bill] to count the bananas (35.52)...TA and [Bill] count the bananas and [Bill] selects 2 (39.05-41.28)...TA moves [Bill] hand from the reader (44.45)...one of the pupils in the adjacent classroom has started to throw a tantrum, [Bill] looks to where the noise is coming from, off task (46.77)...TA redirects attention to CAPE (48.38)...on the comic clip [Bill] smiles broadly and closes his eyes, listening to the audio output (56.68)...when VT tells [Bill] to tidy he does so, looking directly at the folder rather than the reader (58.75)...	Intervention – count with teacher Symbol select – correct symbol Environmental distraction – noise from classroom Intervention – redirect view Symbol select – symbol tidy
The 3 apples task starts, [Bill] looks at the folder and touches the 3 symbol (64.68)...he selects the 3 and smiles broadly, looking again at the screen (67.02)...on the 3 apples comic clip [Bill] smiles broadly, when VT tells off SM [Bill] smiles and rocks in his seat (83.00)...he then removes the symbol from the reader (too early) (84.58) however CAPE has detected symbol removal and moves on to test-learn transition (92.20)...when VT asks [Bill] to do some more counting [Bill] smiles again (100.90)...	Behaviour – checks symbols visually and touches correct one, symbol select – correct symbol Wrong response – premature symbol removal
VT introduces the 4 teddy bears task – going to	

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
demo, [Bill] smiles and listens intently to the VT, he is not looking directly at the screen he has tilted his head toward the speaker (106.88)...	
There is now a lot of noise from the adjacent classroom (111.52)...**during the VT count [Bill] touches each symbol in turn to the beat of VT count (116.02)...when VT says 4 [Bill] touches the 3 and the 4 symbol in turn (119.22) he seems to be trying to select a symbol.**...when VT asks [Bill] to select a symbol [Bill] looks at the screen and smiles (125.08)...[Bill] selects 3 and then changes his mind and puts it back on the reader, selecting 4 instead (130.17)...TA puts the symbol back on the reader (133.15)...when VT asks [Bill] to tidy he does so (138.03)...	Environmental distraction – noise from classroom Behaviour – developing a symbol selection strategy Symbol select – correct symbol/self correct
VT repeats 4 teddy bears symbol (143.15)...[Bill] looks at the symbols on the folder, TA prompts [Bill] to count the bears and she and [Bill] count them (147.18-152.30)...[Bill] selects 4 from the folder and puts it on the reader (153.53)...when the cheering starts [Bill] removes the symbol (156.93)...TA intervenes and [Bill] looks very serious and begins to fight to stop her putting symbol back on reader (158.63)...on the tidy [Bill] smiles and puts the symbol back on the folder (171.78)...	Symbol select – symbol tidy Behaviour – visual scan of symbols Intervention – count with teacher Symbol select – correct symbol
VT introduces the 5 toy cars task, [Bill] taps his finger to the beat of VT count (182.92)...he is now touching each symbol on the folder as well, on the count of 5 [Bill] touches the 5 symbols and looks at the screen (185.37)...[Bill] then selects 5 from the folder (189.45)...he does not put the symbol on the folder, instead he waits until VT asks [Bill] to select a symbol then he selects 5 (195.47)...he places it on the reader until the cheering starts and then removes it (199.90)...TA intervenes (201.22)...[Bill] smiles and looks at the screen (this is his favourite task output), he smiles broadly and moves forward in his seat to get a better look (201.73)...at the very beginning of the tidy task [Bill] removes the symbol (221.38)...there is a lot of noise from the adjacent classroom, he does not seem to be distracted by the noise however (225.18)...	Symbol select – symbol tidy Behaviour – tap finger to VT count. Touch each symbol in order of count Symbol select – correct symbol
VT introduces 4 teddy bears (229.83)...[Bill] looks	Symbol select –

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
to the folder but does not select a symbol. TA prompts [Bill] to count the symbols and [Bill] and TA count the bears (235.50)...[Bill] selects 4 and places it on the reader, he is smiling (241.22)...he removes the symbol and tries to place it on the folder, TA intervenes (244.43)...when VT says well done [Bill] smiles and taps his hand on the folder (253.82)...when VT berates SM [Bill] smiles and puts his thumb in his mouth, watching the screen (257.28)...when asked to tidy [Bill] does so (261.93)... **VT introduces 5 toy cars, [Bill] smiles and looks at the screen (267.48)...[Bill] selects 5 from the folder (269.92)...**[Bill] smiles broadly and stares at the screen (282.40)...[Bill] watches the comic clip and smiles (293.27)...at the end of the comic clip [Bill] puts his hand on the symbol and then removes it when told to (302.97)...there is noise now from a pupil in another class that is throwing a tantrum (307.47) VT introduces 4 teddy bears (308.00)...the noise from the adjacent classroom is louder now, this may be distracting [Bill] (316.72)...[Bill] selects 5 instead of 4 (321.53)...when VT tells [Bill] the selection is wrong [Bill] smiles (327.42)...[Bill] removes the symbol when asked to (331.18)... VT repeats 4 teddy bears task (338.75)...[Bill] touches the 5 but does not select the symbol, TA prompts [Bill] to count the teddy bears and then counts them with him (342.00-347.90)...[Bill] selects 4 from the folder (348.82)...as soon as the symbol is on the reader he takes it off again and tries to remove it again, TA intervenes (352.12) [Bill] holds both her hands and does not let go until the cheering has stopped, he is listening to the audio output by turning his head to one side and shutting his eyes (356.47)...TA places symbol back on the reader (359.58)...during the comic clip [Bill] rubs his eyes with this head pointing down to the folder (363.45)...on the tidy [Bill] removes the symbol as requested by VT (367.35)... VT introduces 5 toy cars task, [Bill] stops rubbing his eyes, looks at the screen and smiles (373.50)...he looks at the folder and touches the	symbol tidy Environmental distraction – noise from classroom Observation – when no demo given [Bill] does not select a symbol; Reliant on visual cues, intervention – count with teacher, symbol select – correct symbol, Symbol select – symbol tidy Symbol select – correct symbol Symbol select – symbol tidy Environmental distraction – noise from classroom Wrong response – wrong symbol Symbol select – symbol tidy Behaviour – visual and physical scanning Intervention – count with teacher Symbol select – correct symbol

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
4 symbol initially (374.83)...TA asks [Bill] if he wants to count the toy cars, she then supports [Bill] while he counts the toy cars (380.07)...[Bill] selects 5 and places it on the reader (386.70)...this time [Bill] leaves the symbol on the reader (391.12)...during the comic clip TA reorders the symbols on the folder (395.45)...[Bill] is smiling as he watches the toy car crash, he enjoys this comic clip (401.78)...VT requests [Bill] to tidy, he does so straightaway (412.02)...	Symbol select – symbol tidy

Behaviour – visual and physical scanning |
| There is some disruption from another class (419.62)... | Intervention – count with teacher
Symbol select – correct symbol |
| VT starts 4 teddy bears task (419.62)...[Bill] did not select a symbol, TA asks if [Bill] wants to count the bears, [Bill] and TA then count the bears (424.58-433.72)...[Bill] selects 3 from the folder and puts it on the reader (433.73)...as soon as the wrong statement starts[Bill] removes the symbol from the reader and places on folder (436.07)...[Bill] smiles at VT, TA places symbol back on reader (439.90)...VT asks [Bill] to tidy and he does so (443.45)... | Symbol select – symbol tidy |
| VT repeats 4 teddy bears, [Bill] listens to the VT output and smiles, his head is tilted to one side facing speaker, he is not looking directly at the screen (449.58)...TA prompts [Bill] to count the bears, the count them together (453.62-459.03)...[Bill] selects 4 from the folder, puts it on the reader (460.02)...he does not initially look at the screen, when the symbol is on the reader he glances to his right to look at the screen and smiles as the cheering starts, he does not attempt to remove the symbol from the reader (464.55)...when VT says well done, [Bill] briefly smiles, he is still glancing at the screen but his full attention is on the video output (469.18) | Environmental distraction – noise from classroom
Intervention – count with teacher

Wrong response – wrong symbol

Symbol select – symbol tidy |
| The child previously throwing a tantrum has become louder now, [Bill] does not seem to notice however (477.00) | Intervention – count with teacher
Symbol select – correct symbol |
| On the tidy [Bill] removes the symbol from the reader as asked (478.88)... | |
| VT plays the intro to 5 toy cars task, [Bill] smiles and taps the folder, he is looking directly at the | |

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
screen now (486.97)...child in other classroom is screaming now (489.50)...the noise from the child throwing a tantrum is becoming distractive to [Bill] (495.42)...[Bill] selects 4 from the folder, he has lost concentration due to noise issue (502.10)...when VT says not correct [Bill] takes symbol off reader, TA intervenes (505.73)...when VT asks for tidy [Bill] carries out task (513.17)...	Environmental distraction – noise from classroom Symbol select – symbol tidy
VT repeats toy cars task, noise disruption continues (517.60)...[Bill] is staring directly at the screen now and is very close to the speaker (519.88)...TA prompts [Bill] to count the cars, she then supports him as he counts the cars (522.42)...[Bill] selects 5 from the folder and places it on the reader (530.08)...TA tells [Bill] to wait (not to remove symbol from reader) [Bill] pauses and then removes the symbol (535.78)...TA intervenes (537.57)...when the 5 toy cars comic clip starts [Bill] moves forward toward screen, smiles and watches clip with excitement (542.42)...when cars crash [Bill] puts his thumb in his face and smiles broadly (545.40)...on the tidy [Bill] removes symbol as asked (555.62)...	Environmental distraction – noise from classroom Wrong response – wrong symbol Symbol select – symbol tidy
VT introduces 4 teddy bear task, another teacher enters room (noise distraction) (559.42)...[Bill] looks toward door, his is off task now (561.92)...TA redirects [Bill] back to CAPE (563.40)...TA asks [Bill] to count the teddy bears, holds [Bill] hand, [Bill] points his right index finger at the screen and TA and [Bill] count the teddy bears on screen (576.60-582.42)...[Bill] selects 4 and places it on the reader (584.77)...[Bill] does not attempt to take the symbol back of the reader as he has before (587.45)...[Bill] watches output from CAPE and smiles, the background noise is getting louder now (595.25)...at the end of the comic clip [Bill] prepares to remove symbol but only does so when asked by VT to do so (602.05)...	Intervention – count with teacher Symbol select – correct symbol Symbol select – symbol tidy
VT introduces 5 toy cars task (610.13)...[Bill] stares at screen but does not react to request, the noise from the child having a tantrum is much louder now and may be distracting [Bill] now (612.17)...005 puts his hand on the 5 symbol and looks back at the screen again (615.48)...[Bill]	Environmental distraction – noise from classroom Behaviour – off task, distracted Intervention – count

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
places the 5 symbol on the reader and looks at the screen, he is not smiling now, the noise from the tantrum child is still very loud and distracting for [Bill] (617.72)...as soon as the cheering starts [Bill] removes the symbol from the reader (619.77)...TA intervenes by making [Bill] put the symbol back on the reader (623.98)...when the comic clip starts [Bill] looks directly at the screen and smiles, he watches the entire sequence before looking at the symbol again in preparation of removing from reader (630.52)...on the tidy [Bill] pauses before removing the symbol from the reader as requested (642.62-648.97)...the background noise continues	with teacher Symbol select – correct symbol Symbol select – symbol tidy Environmental distraction – noise from classroom
VT introduces the 4 teddy bears task, [Bill] watches the screen intently perhaps expecting the demo output (654.45)...when nothing happens he looks at the symbols and touches each one in turn, perhaps trying to choose one (658.48)...then he touches the reader with his finger (658.00)...then back to the folder and looking at the symbols, he is touching the 4 symbol (659.48)...he selects the 3 symbol which is next to the 4 on the folder (662.73)...when the wrong clip plays [Bill] removes the symbol again, TA intervenes (665.55)...the tantrum continues!	Symbol select – correct symbol Environmental distraction – noise from classroom Symbol select – symbol tidy
TA reorders symbols so that all can be seen by [Bill], previously two were staked one on top of the other 3 and 4 (672.30)...VT asks [Bill] to tidy (672.65)...	Environmental distraction – noise from classroom
VT repeats 4 teddy bear task, [Bill] smiles and watches video output, he taps the 3 symbol with this finger (677.43)...[Bill] selects the 3 symbol again (681.68)...when the wrong clip starts [Bill] smiles and listens to VT talking (is he deliberately trying to get task wrong so he can listen to VT talk?) (684.48)...on the tidy [Bill] removes symbol as asked (691.77)...however, he keeps his hand on the 3 symbol after selection and tilts his head toward the speaker to listen to VT talk (695.03)...TA sees this and reorders symbols (700.62)...	Behaviour – attempt to create a counting/selection strategy Wrong response – wrong symbol
VT is now playing the 4 teddy bears demo clip (700.62)...as VT counts [Bill] looks at the symbols on the folder and taps his finger to the VT count	Intervention – symbol reorder Symbol select –

419

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
beat (706.52)...TA redirect [Bill] to screen (707.63)...[Bill] selects 4 from the folder without being prompted by the TA (711.62) and places it on the reader (712.62)...for some reason the TA intervenes removing the symbol from the reader! (719.70)...VT asks [Bill] to select a symbol (719.70)...[Bill] is now confused and selects 3 from the folder (722.55)...he puts it on the reader (723.92)...on the wrong sequence [Bill] looks despondent, this may switch him off task (727.28)...[Bill] removes the symbol from the reader just before being asked to do so (730.70)...he removed it just too early, but [Bill] has realised this and self corrects, placing symbol back on reader and then removing it when asked to do so by VT (735.90)...	symbol tidy

Wrong response – wrong symbol

Observation – [Bill] seems to enjoy output even when wrong, is he trying to get wrong answer
Symbol select – symbol tidy |
| TA redirects [Bill] view to CAPE (748.50)...**[Bill] points to screen and starts to count the teddy bears, TA joins in verbalising each number, this is the first time that [Bill] has independently prompted to count the objects on screen (749.13)**...[Bill] selects 4 and puts it on the reader (751.50)...as soon as the cheering starts he removes the symbol, TA intervenes (754.93)...[Bill] looks at screen and watches comic clip, he is smiling now (759.22)...on the tidy 004 does the tidy task (769.17) | Behaviour – tapping finger to VT count
Intervention – redirect view,

symbol select – correct symbol
intervention un-necessary
Wrong response – wrong symbol |
| VT introduces 5 toy cars task (774.58)...[Bill] is now fully focused on the task output (774.58)...when asked to choose [Bill] looks at the folder and touches the 4 symbol, he then looks at the screen and smiles (781.25)...he selects 4 and puts it on the reader (785.35)...when the wrong clip plays [Bill] stops smiling and removes the symbol from the reader (788.73)...TA intervenes (790.95)...when asked to tidy [Bill] removes symbol and puts on folder (794.73)...he continues to hold the 4 symbol however (797.47)...the noise from the adjacent classroom has started to rise again (801.85)...**TA prompts [Bill] to count but this time he puts his finger on the screen and TA verbalises the number names (807.28)**...[Bill] selects 5 and puts it on the reader (812.97)...as soon as cheering starts [Bill] removes symbol again, TA intervenes but [Bill] puts symbol on folder anyway (816.83)...[Bill] looks at screen and smiles, he | Symbol select – symbol tidy/self correct

Observation – initiation of independent counting of symbols on screen

Symbol select – correct symbol |

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
watches comic clip until crash sound starts then he closes eyes and smiles, listening to audio (828.32)...when the audio clip stops [Bill] opens his eyes and looks at the screen, smiling (836.37)...**CAPE will not continue until [Bill] places the symbol back on the reader. [Bill] realises this and puts it back on the reader (840.45)**...	Symbol select – symbol tidy Wrong response – wrong symbol
When asked to tidy he does so (844.42)...the school bell rings and [Bill] stops what he is doing and listens to it (847.37)...	Symbol select – symbol tidy
VT introduces 4 teddy bears task (847.37)...when asked to select he looks at folder but does not select a symbol, the noise from the other classroom has risen again and is very distracting (854.58)...TA moves the folder closer to [Bill], he selects 4 from the folder, this is selection is more likely due to the placement of his hand (4 closest to hand) than to a conscious choice of symbol base on task (859.52)...he places this on the reader (861.98)...when the cheering starts he removes the symbol from the reader (865.15)...TA does not intervene...[Bill] looks up from the folder when comic clip plays and smiles at the screen (871.38)...when the comic clip ends [Bill] places symbol back on the folder (self correct premature symbol removal) (880.47)...when the tidy starts [Bill] removes the symbol again as requested (882.85)...TA reorders symbols (889.58)	Intervention – count with teacher Symbol select – correct symbol Symbol select – symbol tidy
VT introduces 5 toy cars (889.58)...when VT asks how many toy cars [Bill] points to the screen to prompt counting, TA verbalises numbers and [Bill] counts (892.43)...[Bill] scans symbols on the folder and then selects 5 from the folder, placing on the reader (896.83)...[Bill] puts the symbol close to the reader and when activated he puts it back in the folder (899.92)...this time TA prompts [Bill] to put the symbol back on the reader (905.15)...when TA is not looking [Bill] puts symbol back on the folder (910.23)...TA prompts [Bill] to put the symbol back again (912.32)...[Bill] does not react he is listening to the crash sequence (915.62)...TA prompts [Bill] to put symbol back, he looks from the folder and places his empty hand on the reader (918.72)...TA points to symbol and he	Environmental distraction – noise from classroom Symbol select – correct symbol Symbol select – symbol tidy Intervention – reorder symbols

Video transcript of session 9 (symbols 2, 3, 4, 5)	Codes
puts it on the reader as requested (921.30)...on the tidy [Bill] removes it again and puts on the folder (924.70)... TA prompts finish (928.63)...TA gives [Bill] the finish symbol, he takes it and puts it on the reader (932.60)...on the tidy [Bill] removes the symbol Session finished (936.28)...	Symbol select – correct symbol Symbol select – symbol tidy Intervention – prompt finish Symbol select – select finish

Appendix P – Post main study teacher interview schedule

Semi structured interview with teachers 5 weeks after the study

Introduction

1. The reason I have asked to talk to you today is to discuss the research study conducted in January and February this year.

Participant profile prior to study

2. At the beginning of the study how did [participant name] communicate?
3. Was he\she verbal at any time?
4. Do you think he\she was able to talk before the study began?
5. What about [participant's name] exposure to computer programs prior to the study. Would you say that he\she was a frequent user of computer systems?

Taking part in the main study

1. How did [participant name] cope with using CAPE when he\she was first introduced to it?
2. Do you think that [participant name] found CAPE easy to use?
3. What about aspects of the system that [participant name] found harder to use?
4. What about the level of challenge, how do you think [participant name] the complexity of the tasks they he\she was set?
5. Which tasks did he\she find easy?
6. What about more complex tasks, how do you feel [participant name] was able to cope with harder tasks?
7. CAPE uses a very repetitive teaching method how do you feel this effected [participant name] ability to learn new symbols\skills.
8. What new skills, if any did he\she learn?

CAPE functionality

9. Going back to the computer program, were there any parts of the application you liked?
10. Were there any parts of the system that you felt did not work as well, or could have been improved?
11. When you first used the program, did you find it easy to use or was it a bit complicated?
12. Therefore, what did you think about using symbols to interact with the system? Do you think the symbols worked well or do you think that it would have worked just as well with say a touch screen?
13. How did you find the virtual tutors voice, do you think it was clear or did it make life harder for the children?

Technology and software in the classroom

14. Do you currently use technology in the classroom to teach curricula subjects and if so what do you use if for?
15. What are the downsides for using computer programs in the classroom?
16. Do you think that if computer programs like CAPE were available to use in the classroom, would you use them?

Post study behaviour

17. Once the study had finished did [participant name] behaviour change?
18. How would you say [participant name] communication has changed after taking part in the study?
19. What about behaviour changes, do you think you have seen any changes in the children's behaviour over the study or after?

Any other questions

20. Is there anything that we have not discussed that you would like to raise before we finish?
21. Ok, thank you for that. How did you feel about giving an interview, do you feel it went ok.

Thank you very much for taking the time to talk to me.