Adding Sign Language Animation to the ECHOES Multimodal Technology Enhanced Learning Environment

Elaine Farrow
Heriot-Watt University
Edinburgh
UK
E.Farrow@hw.ac.uk

Oliver Lemon
Heriot-Watt University
Edinburgh
UK
O.Lemon@hw.ac.uk

ABSTRACT
We describe the ECHOES technology enhanced learning environment, which uses a virtual character (VC) to engage young children in social games. The VC is already capable of performing a limited set of gestures from the Makaton language programme to accompany pre-recorded speech.

We then introduce and motivate our proposal to enhance the system's communication options with the addition of phrases in both British Sign Language and Sign Supported English, to be integrated with the existing pointing gestures and gaze behaviour. These will replace the pre-recorded speech used to engage the child's attention and direct their actions during the learning activities.

The current system targets both typically developing (TD) children and those with autistic spectrum disorders (ASD). As deafness is relatively more common in ASD children than TD, and TD deaf children with hearing parents are known to show delays in language-related theory of mind (such as joint attention) we expect that our extended system will bring new opportunities for research into the educational development of deaf children, both TD and ASD.

Categories and Subject Descriptors
J.4 [**Social and Behavioral Sciences**]: Psychology – *educational psychology, technology-enhanced learning.*

General Terms
Experimentation, Human Factors

Keywords
Deaf, TEL, Sign Language, BSL.

1. INTRODUCTION
ECHOES [2] is a multimodal technology enhanced learning (TEL) environment which uses a child-like virtual human character to interact with young children (age 5-7) in a series of social games. It provides opportunities for both typically developing (TD) children and those with autistic spectrum disorders (ASD) to practice social interaction and communication skills such as turn-taking and collaboration in a safe and predictable environment.

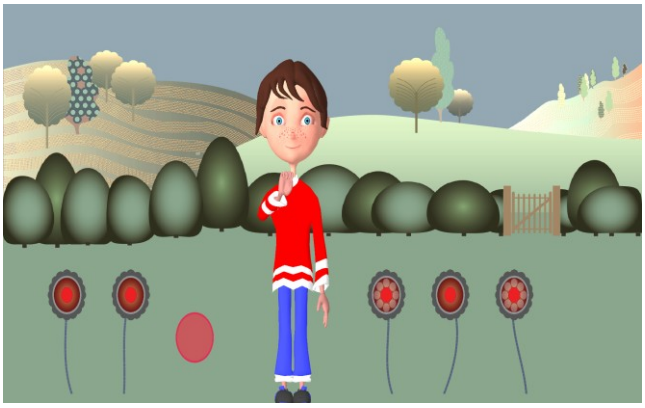

Figure 1: The VC uses the Makaton gesture for "your turn".

The virtual character is driven by an intelligent agent capable of planning, goal-directed behaviour, and emotional affect. The system uses recordings of a real child's voice in conjunction with facial expressions and purposefully directed gaze to interact with the child, encourage joint attention, and create emergent narratives. The VC can also perform a small set of manual gestures in Makaton[1] ("your turn", "my turn", and "all done") (see Figure 1).

We propose to translate the voice-recorded phrases into both British Sign Language (BSL) and Sign Supported English (SSE) and integrate them with the other aspects of the character's communication (including gaze and pointing). This will allow the system to be used by deaf children, both ASD and TD, providing us with insights into this under-researched population and an indication of the potential of technology-enhanced learning to aid their development.

2. DEAF CHILDREN AND AUTISM
Deafness, while rare, is relatively more common in children with ASD than in the general child population. "Severe and profound hearing loss is uncommon among children with autistic disorder.

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[1] http://www.makaton.org/about/about.htm

However, the prevalence (3.5%) is at least 10 times that reported in epidemiological studies of children from the general population." [7]. "Whilst in a typically developing population the incidence of deafness is 1.3 per thousand for example: in the case of Autistic Spectrum Disorder it is thought to be 9 per 1000, in the case of learning disabilities 4.2 children per 1000 are thought to have a hearing loss." [4]

In addition, the National Deaf Children's Society (NDCS) reports that 40% of deaf children have additional needs. "The most prevalent disabilities that may co-occur with hearing loss are learning disabilities, attention disorders, cerebral palsy, and visual impairment." (Roush et al., 2004, cited in [5]).

However, even where a deaf child has no additional needs, the language barrier can lead to difficulties with social skills such as those addressed by ECHOES. It is a widely quoted statistic that 90% of deaf children will be born to two hearing parents with no previous knowledge of deafness. Many of these children will go on to use hearing aids or cochlear implants and attend mainstream schools, but their deafness may nevertheless impact negatively on both academic performance and socialisation. Nunes et al. [6] found that while deaf children are not rejected by their peers, they are often neglected and are significantly less likely than their hearing peers to have a friend in their class.

Meristo et al. [3] looked at the development of Theory of Mind (ToM) in TD hearing children and deaf children with hearing parents (8 months - 35 months). They reported that "even at a very early stage of language development, deaf children of hearing parents do worse on ToM measures than do hearing children" indicating that "access to a theory-of-mind mechanism seems to be dependent on early access to language." They go on to say that "the role of language in this case seems to be coordination of minds in a conversational context (e.g. joint attention or early pragmatic understanding) rather than specific structural parts of language (e.g. complement clauses)." Joint attention is one of the areas specifically targeted by ECHOES.

3. LANGUAGE CHOICE

As national sign languages differ between countries, we restrict ourselves to the considering the situation in the UK.

3.1 History of Deaf Education in the UK

Ever since the first schools for the deaf were established in the 18th century[2], there has been disagreement over the best methods to use to educate deaf children: is it better to develop their competence in the spoken language of the majority population through speech training and lip-reading, or should some form of manual system be used (for example sign language, gesture systems, or finger-spelling)? At a conference in Milan in 1880, the leading educators of the day rejected manual communication entirely and decided that the 'oral method' (characterised as "just speak to the children as if they were hearing" [8]) should be used exclusively in schools throughout Europe.

The oralist philosophy continued to dominate until the late 20th century. Sign language was regarded as a primitive form of communication and its users were accorded low status. [8] reports that "by the 1950s, Deaf children in school were unlikely ever to meet a Deaf adult – and certainly never see a Deaf adult signing as part of their education." Nevertheless, deaf children at residential schools learned to sign from their peers, with greater input from the few who had deaf signing parents. After leaving school, they would meet in Deaf clubs, which thus formed the basis of the local Deaf community.

Things began to change in the 1950s as university researchers took an interest in signed languages. The linguist Dr William Stokoe in the USA was the first to recognise that American Sign Language was far more than a primitive gesture system and that in fact it had all the features of a natural human language. Research has continued and now there is no doubt that sign languages are capable of fulfilling every kind of communicative function just as well as spoken languages. FMRI scans have shown that the same areas of the brain are used to process spoken and sign languages, and that mime and gesture do not provoke the same response.

The legitimacy conferred by research raised the status of sign language. In the UK, British Sign Language (BSL) was named by Dr Mary Brennan in Edinburgh in 1976 and began to be used in schools. "By the mid 1980s more than half of schools for the Deaf had begun to use sign language in at least some classes." [8] and many hearing people attended evening classes to learn BSL. The Deaf community became increasingly political, demanding official recognition for their language (which came in 2003).

The next major change came with the government review of educational provision for children with disabilities (the Warnock Report) in 1978. It noted that the academic attainment of children in special schools was often far below that of their contemporaries and advocated for change. Government policy changed accordingly, and there is now a presumption that children with disabilities will attend mainstream schools wherever possible. "In 1993, the general principle was enshrined in UK law that children with special educational needs should normally be educated in mainstream schools if the parents wanted." (Powers, 2002, cited in [8]).

However, for deaf children, this can lead to social isolation. Instead of being surrounded by other deaf children in a residential setting, they may find themselves as the only deaf child in a mainstream school. There are no longer opportunities to learn BSL informally from peers, and children who struggle to pick up English can be left without a "first language". A study by Nunes et al. investigating the social status of deaf and hearing pupils in two mainstream schools in London found that two-thirds of the deaf pupils had no friends in their class, compared with 23% of their hearing classmates. These children were not 'rejected' by their contemporaries but instead 'neglected'.

"Some of the hearing pupils experienced communication difficulties as a clear barrier and did not seem to think that these barriers can be overcome. … The mere exposure to the deaf peers did not result immediately in more understanding and greater awareness of how to communicate with the deaf." [6]

3.2 Languages used in the classroom

Deaf children in the UK are taught through a variety of methods. The majority will attend mainstream schools where they may be

[2] For example, the first school for the Deaf in Edinburgh was set up in 1760 [8].

the only deaf child; others will be part of a small group of deaf children in a special unit attached to a mainstream school; fewer still will attend a special school. The language used in the classroom in each of these settings is different. We will take these variations into account when extending the ECHOES system. Here we consider three possible language choices.

Makaton is a structured language programme which uses signs and symbols to help people communicate. It is used primarily to support children with cognitive rather than hearing impairments. Although Makaton borrows some signs from British Sign Language, it is not itself a language. It is used in conjunction with spoken language, with the signs and symbols following the spoken word order. The sign vocabulary is very limited and may not be able to fully represent the content of the audio clips to those who cannot hear them.

In contrast, British Sign Language (BSL) is a full natural language, the first language of those who identify as culturally Deaf with a capital 'D', with a grammar (and word order) distinct from English. Other countries have their own national sign languages, and many are mutually unintelligible. Sign languages are capable of expressing anything a spoken language can express.

Between the restricted vocabulary of Makaton and the full expressive power of BSL lies Sign Supported English (SSE), using individual lexical items from BSL but following English word-order and grammatical structure. Hearing BSL learners whose first language is English typically produce SSE without realizing it; many teachers and communication support workers who work with deaf children will be in this position.

Our intention is to add BSL lexical items to the ECHOES system and use these to produce phrases in both BSL and SSE, allowing us to select the best communication option for the particular context when we carry out evaluations with our target population.

3.3 Language used in ECHOES

The pre-recorded sound clips used in the current ECHOES system are typically very short. Many are reactions to the child's action ("Cool!", "Good job!"). Others direct the child to carry out an activity ("I know! Let's grow flowers in these pots", "Let's tidy up these balls"). Some contain references to unique objects in the scene ("Look! The ball changed colour!"), whose physical location will be needed to produce a complete signed utterance. However, the system already uses location information to generate gaze and pointing gestures (see Figure 2).

4. THE ECHOES SYSTEM

4.1 Description of ECHOES

ECHOES is a technology-enhanced learning environment aimed a young children and featuring a child-like virtual character. The interaction between the child and the VC is based around cooperative play. The child uses a large touchscreen to manipulate objects in a garden scene; for example, picking flowers. The character directs the child's attention through gaze and pointing as well as pre-recorded speech (see Figure 2).

The VC is driven by an intelligent agent with a set of goals and a set of strategies to achieve them. The agent is based on the FAtiMA architecture, which was designed to control the behaviour of emotionally intelligent virtual characters (Dias and Paiva, 2005, cited in [2]). FAtiMA has a deliberative level, supporting goal-oriented behaviour, and a reactive level to drive the emotional reactions of the agent.

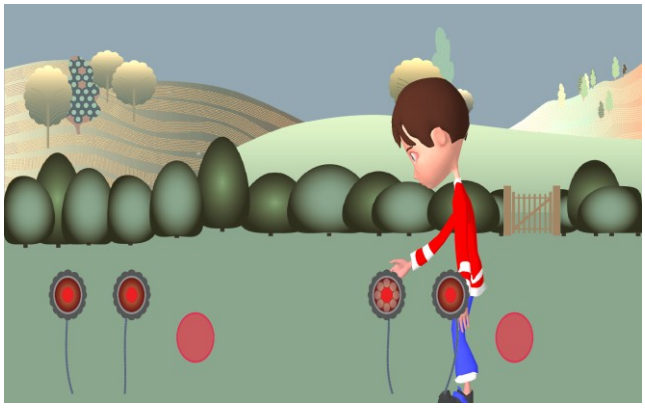

Figure 2: The VC shows the child which flower to pick using gaze and pointing.

The current system has no speech recognition, so there is no requirement to explore sign recognition for comparability. Dynamic language generation in ECHOES occurs at the strategic level rather than at the level of surface realisation, meaning it will be possible to hone the animation of the specific phrases we use to improve intelligibility. We will ask educators and signing colleagues to evaluate the acceptability and clarity of our generated signing before we trial the system with deaf children.

It is important to note that the animations are generated dynamically, taking into account the current locations of objects in the scene. Many of the activities involve moving objects from one location to another, for example stacking a set of pots (see Figure 3). The system keeps track of the objects so that the agent's gaze and pointing gestures are always directed to the correct location. The system's current behaviour fits well with the use of space in BSL.

The system is designed to support research into social and emotional behaviours. The activities in ECHOES are founded on the Social Communication, Emotional Regulation and Transactional Support (SCERTS) model of assessment and intervention for children with Autism Spectrum Disorder (Prizant et al., 2006, cited in [2]), "an educational model for children with ASD that embeds assessments and interventions designed to support social communication, emotional regulation, and transactional support into a child's daily routine" [2].

ECHOES presents several distinct learning activities, designed in conjunction with educational practitioners through a participatory design process. In many of these, the character will demonstrate an action for the child to copy. Once the child has carried out the task correctly, they will subsequently take turns. The focus is very much on the visual aspect, and the language used is designed to be simple, direct, and child-friendly.

Nevertheless, we expect that children in the target population (age 5 to 7 years) will sometimes need to be supported in their use of ECHOES. For example, a classroom aide may work with the child and repeat or clarify task instructions. The software control panel also provides options for the VC to repeat a bid for interaction, or to take another turn if the child is not responding.

While we hope that our BSL and SSE animations will be clear and comprehensible, we do not consider it to be a problem if a child needs further clarification from a human helper.

We will also familiarise ourselves with other projects which have developed BSL virtual characters, from Tessa [1] to the present day, and use the results of those projects to guide our system development.

Figure 3: The VC demonstrates how to stack the pots. As the objects are moved, the system keeps track of them so that gestures always refer to the correct location.

4.2 Technical Considerations

ECHOES uses the Piavca package (Gillies, 2008, cited in [2]) for animation of the virtual character. As mentioned previously, the virtual character already performs several Makaton gestures, indicating that it is technically feasible to add BSL production. We note that the system does not currently use a notation system supporting sign language (e.g., HamNoSys), and we will investigate the possibility of adding such support.

We have access to skilled interpreters and signers, and both high-definition video recording and motion-capture technology. The translated phrases will of course need to be edited to allow object locations to be specified dynamically.

Additional technical possibilities that we will explore in our extended system will be the use of new multimodal input technologies such as the Kinect controller to detect some aspects of child behaviour during interactions with the VC.

The ECHOES system is an ideal vehicle for bringing together sign language animation and TEL for the benefit of deaf children. A summative evaluation of the current system is underway and preliminary results suggest that it has succeeded in its goals of encouraging and supporting communication. Once our enhancements are in place, we hope to be able to conduct similar trials with children in deaf units and specialist deaf schools.

5. CONCLUSION

We have briefly described the ECHOES TEL environment, where both typically developing children and those with autistic spectrum disorders can interact with a virtual character to perform cooperative tasks in a series of learning activities and social games, as a means to practice and develop social and communicative skills.

We argued that these skills are of particular relevance to deaf children and discussed our intention to enhance the system's functionality by using dynamic sign language animation to replace the pre-recorded sound files currently used. We acknowledged the need to look more closely at the issue of language choice for deaf children, particularly those who also have ASD, and indicated that we will target both BSL and SSE phrases.

We believe that the ECHOES system, with the additions we propose, will bring new opportunities for studying the educational development of deaf children, both TD and ASD.

6. ACKNOWLEDGMENTS

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