

ECHOES II: Improving Children's Social Interaction through Exploratory Learning in a Multimodal Environment

Case for Support (Outline Proposal)

Overview

ECHOES II aims to build on the interdisciplinary and innovative work of ECHOES (TEL1 small grant, 2006/7) to develop an adventurous technology-enhanced-learning (TEL) environment in which both typically developing (TD) children and children with Asperger Syndrome (AS) at Key Stage 1 (ages 5-7) can explore and improve social interaction and collaboration skills. The environment will also serve as a tool for researchers, teachers, parents, and practitioners to investigate problems that children may encounter in specific social contexts and the ways in which those problems may be addressed. The environment and its uses will be defined based on key theoretical frameworks with clear social and educational underpinnings. The learning outcomes envisaged include improved ability and motivation for children to engage in social interactions, including transactional, collaborative, and conversational exchanges, and will be evaluated in controlled studies using established metrics, for example Psychoeducational Profile-Revised (PEP-R) (*Schopler et al., 1990*).

The proposed environment will combine existing technologies such as interactive whiteboards, gesture and gaze tracking, and intelligent context-sensitive interfaces to create, with the active participation of user groups, a novel interactive multimodal environment that can be adapted easily to the needs of specific individuals, and that can provide new ways of investigating and supporting the development of social skills in children.

The proposal is founded on socio-cognitive theories and on specific educational and social abilities of children. This is both a challenge and an inspiration for the technology required to realise such an environment. It is a challenge because the environment must be usable by and adaptive to children, including those with AS, it must be educationally and socially viable, and it must enable transfer of the skills acquired to the real world. The socio-cognitive theories are an inspiration because meeting their requirements dictates innovative use of the state of the art in educational technology, techniques in artificial intelligence in education, multimodal interfaces, affective and social computing, educational games, and tangible technologies. The success of this project depends fundamentally on complementary input from the fields of social and learning sciences, from intelligent, context-aware computer technologies and emerging hardware tools (e.g. eye-tracking and tangible devices), as well as educational practices and learner requirements. A truly interdisciplinary consortium comprising experts in the fields of social science, developmental psychology, special education, arts, assistive technology, computational linguistics, technology enhanced learning, affective computing and game technology will contribute to the deployment of the existing theories and TEL practices for children in real educational contexts. Engagement of practitioners and learners in the design of the environment is core to the project's success.

Objectives

ECHOES II has two overarching objectives: (1) to develop and deploy an augmented reality environment to provide children of different cognitive abilities with scaffolded exploration of social interactions. Such experiences will enable children to engage in exploratory learning of different kinds to achieve communicative and social goals in collaborative tasks. The second aim is (2) to develop a methodology and tools through which (a) parents and practitioners can examine the specific difficulties that children may encounter in different types of interactions, and (b) researchers can investigate the relationships between children's social skills, communication and learning. The main objectives described above give rise to 4 detailed research goals (A-D):

A: Establishment of a comprehensive set of interactive tasks capable (individually and in combination) of supporting exploration of different aspects of social engagement by children. This objective is motivated by the importance of learning through social attention known to impact on

language development and on general cognition (MRC, 2001). The interactive tasks can be used in establishing appropriate remediation strategies, particularly for individuals with AS. Based on the findings of the ECHOES project, highlighting the fact that no single theory fully accounts for all pre-requisites of social interactions, four key frameworks for cognitive and interpersonal development provide the basis for the interactive tasks that underpin the educational design of the learning environment: (1) *theory of mind*, which explores the ability to reason about mental states of others (Baron-Cohen, 1995), (2) *executive functioning*, which refers to functions such as initiating, sustaining, shifting and inhibition/stopping (Ozonoff et al., 1991; Denkla, 1996), (3) *central coherence* (Happé & Frith, 2006), with its emphasis on the ability to integrate pieces of information into coherent wholes, including the ability to reason about and to understand one's own mental activities, thoughts, beliefs and feelings, and (4) *inter-subjectivity* (e.g. Jordan, 1999; Hobson & Lee 1999), which emphasises the importance of emotional engagement for meaningful learning and suggests that many processes presumed to be purely cognitive are part of a larger dynamic system of affective and affiliative processes (Schopler & Mesibov, 1995). Whilst TD children will demonstrate, to some degree, the different abilities identified by these theories, individuals with AS will show developmental abnormalities in some or all of them (Happé & Frith, 2006). Crucially to ECHOES II, Jordan & Powell (1995) argue that people with AS lack a sense of experiencing self as a necessary element of one's moment-to-moment self-awareness in one's perception of the world.

Following the theoretical accounts, the interactive tasks in the proposed environment will be structured around three levels of engagement: (Level 1) the '*magic mirror*' where children will engage in interactive tasks designed to support their discovery and awareness of self; (Level 2) *transactions* where children will explore their skills related to transactions with others (emphasis on awareness of others' needs, and negotiation of object sharing and physical spaces); (Level 3) *interactional communication* to allow children to engage in routine exchanges with others (e.g. good morning, goodbye, etc.) and to report on their feelings, needs, wants, goals, and plans. The specific tasks within the three levels will be designed in relation to the specific cognitive ability tests proposed in the theoretical frameworks. A working assumption of ECHOES II is that an environment and interventions that are beneficial for children with AS may benefit all children (Rajendran & Mitchell, 2007; Mackay & Dunlop, 2004).

B: Deployment of participatory and learner-centred research and design methodology. Learner-centred participatory design approaches are crucial to designing educational software for children, as it is often difficult for adult designers to understand children's abilities, needs, and desires without consulting them directly. Giving children a voice in the design process ensures that their sensibilities are incorporated into the design from the outset, rather than at prototype stage, when it is often too late to change the design of the system significantly. To date, very little participatory design work has involved young children with AS (with the notable exception of Keay-Bright, 2007a). This is probably because a successful design team requires strong communication skills (e.g. an ability for team members to articulate *what* they like and *why* they like it), which are typically underdeveloped in young children with AS. The results of the pilot study conducted during ECHOES (children with AS, average age 11), suggest that older children with AS are able to articulate and expand upon their design preferences. For this reason, in ECHOES II we propose to establish a design team involving both children of the target age range and older children, parents of children with AS, their teachers and carers. This will allow us to build up a rich picture of the desires and requirements for the environment. The design of the environment will employ a learner-centred, participatory design approach based on the CARSS framework (Good & Robertson, 2006) which will be extended to accommodate the involvement of children with AS.

C: Implementation of the learning environment that will facilitate the development and exploration of social skills in children. This will be an augmented-reality interactive whiteboard environment, using a combination of video-projection, gesture mapping and recognition, 3D virtual reality, and acoustic signal processing. It will be built and evaluated incrementally as shown in figure 1 (stages 1-4), based on existing technologies. The main technological research challenge is to combine the technologies in a robust real-time system, with data-collection capabilities, that are adaptive to different individuals. Versions of the environment will be designed for different skill-sets, using participatory methods to yield inclusive technology appropriate for a wide range of users and building on recent research in HCI and media technology. Specifically, our starting point (Stage 0 in figure 1) is the existing Reactive Colours

environment (Keay-Bright, 2007b). Stage 1 will add a “magic-mirror” capability to Reactive Colours, using video-projection technology, and acoustic reactivity (visual feedback of the child's verbal behaviours), to enable exploration of basic issues in embodiment and recognition of self. Stage 2 adds a 3D environment and the technology to track the bodily and facial gestures of the child, and their gaze. This will facilitate exploration and support of attention and gestural communication in object-based interaction, under various controlled conditions. Stage 3 adds objects and other actors/agents with whom the child can interact. Here, adaptive speech and gesture synthesis may be used by the virtual actor, and the child's basic communication actions will be interpreted via gesture and facial recognition. Stage 4 adds eye-tracking technology and integrates the multiple information sources and processing channels to produce a complete ECHOES experimental and social-skills support platform.

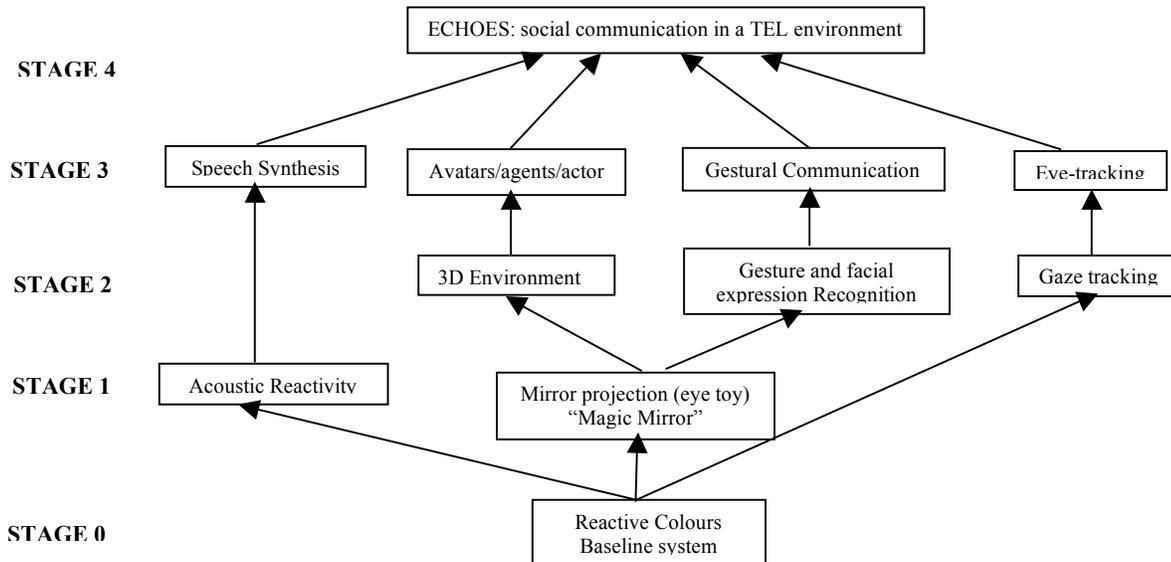


Figure 1: Incremental Development Plan for ECHOES II technologies

D: Development of new evaluation metrics for effectiveness of the interventions and learning outcomes. The diagnostic, formative, and summative assessment framework proposed for ECHOES II will assist the researchers in refining the environment and improving learning outcomes. By putting the needs of the child first, it will help us to understand and to reflect individuality, and the idiosyncratic responses that all children present. The assessment framework constitutes a workbench for systematic assessment of each child in relation to the social and communication skills proposed by the four cognitive theories on which the ECHOES environment will be based. Assessment will be a flexible and scalable process that will evolve alongside the technology, ensuring that we are guided by the child's exploration of the environment at each stage and guidance from teaching and support staff. We will use existing formal assessments to estimate developmental functioning of individual children as a baseline. The PEP-R metric offers a standardised norm-referenced test based on typical development sequences that describe a child's performance. It was developed for children within the chronological age range of 6 months to 7 years. Used as an assessment, PEP-R provides information on developmental functioning in Imitation, Perception, Fine Motor, Gross Motor, Eye-Hand Integration, Cognitive Performance, and Cognitive Verbal areas. PEP-R also identifies degrees of behavioural differences in Relating and Affect (cooperation and human interest), Play and Interest in Materials, Sensory Responses, and Language. The strength of PEP-R is that it can evaluate both developmental delay and atypical behaviours with developmental scales that highlight where a child is functioning relative to peers. Other more informal assessments will be developed alongside the ECHOES II environment to consider understanding and application of social and communication skills in the context of TEL and the curriculum. Examples of methods are interviews (historical profile, quality of dynamic social and communication skills, multiple informants), observation (assessing behaviours in a natural environment), video analysis, and questionnaires.

Organisation of work, milestones, and timeline

To achieve its objectives, the ECHOES II will be divided into 4 parallel but interwoven work strands, with 10 milestones spread over 3 years:

Strand 1: participatory design and formative evaluation: initial design (M1.1, month 6); exploratory studies of learners' social interaction skills (M1.2, month 12); development of evaluation metrics for effectiveness of interventions and for learning outcomes (M1.3, month 18); evaluation of impact of interaction in the environment on learners' social skills (M1.4, month 36);

Strand 2: development of "magic mirror" basic environment (M2.1, month 9), and game based 3-D environment (M2.2, month 18), incorporating gaze tracking, gesture and facial expression recognition, to provide levels 1 and 2 of the ECHOES II environment. The development of these will build on Reactive Colours and the TLRP funded STAGE project. The 3D environment will be further developed to include simple scripted scenarios (M2.3, month 24) in relation to specific tasks;

Strand 3: agent enhanced 3-D environment (M3.1, month 30) extends level 2 to incorporate speech synthesis and gestural communication with the learner;

Strand 4: use of versions of the environment to evaluate research questions relating to representation, attention, gestural communication and recognition (M4.1, month 36); assessment of contribution of ECHOES II studies to current theory in related disciplines (M4.2, month 36).

We have considered the ethical issues involved in all of these tasks, and will work within the ethical guidelines and frameworks in place at all relevant institutions.

Contribution and fit to TLRP: This proposal seeks to improve learning outcomes, targeting social interaction and communication skills, for children at KS1 in a rich TEL context. Our proposal is strongly interdisciplinary, it will develop research capacity, and builds on prior TLRP research (e.g. ECHOES and STAGE). It also complements the 3 large projects funded under TLRP 1 both in terms target age group and learning domain. All project members are committed to active participation in the TLRP community.

Meeting the TLRP challenges: ECHOES II puts primary emphasis on three of the focal challenges of the TLRP call: (1) *personalisation*, (2) *inclusion* and (3) *flexibility*. By focusing on both TD and AS ECHOES necessitates the development of interactive tasks, assessment measures, and interventions that are appropriate to the varying abilities, needs and developmental pathways of individual children. By providing comparable learning experiences to children with a wide range of cognitive and social abilities and ages, ECHOES facilitates inclusion and personalisation on a grand scale. Furthermore, ECHOES will build on state-of-the-art technology available in schools, labs and the game industry such as interactive whiteboard, eye-tracking and augmented reality game environments to promote flexibility and accessibility of the learning experience.

Contribution and fit to the specific TEL call: The proposal meets the TEL 2 aims in developing a strongly interdisciplinary and innovative research collaboration focused on creating and exploiting new learning opportunities by combining human-computer interface technologies, developmental psychology, user-centered design, education, and cognitive science. The project involves greater risk, in its development of new TEL environments and the related analytic challenges, than the normal operation of the TEL market provides. As we discovered in ECHOES, the high-level innovation planned in Echoes II requires the investigators to collaborate and combine research perspectives at a conceptual and methodological level first and foremost, before feeding into technology development. Our research design is built around the learning outcomes in social and communication skills development that we now believe are possible using a wide range of interventions in our proposed environment. As explained in detail above, we propose a clear data-driven methodology, using control groups where possible, to assess the outcomes and effectiveness of interventions.

Project Partners and Interdisciplinarity: Our proposed research design has grown from a challenging interdisciplinary collaboration (in ECHOES) between experts in the social sciences and in new technologies across the UK. This has already provided important new interdisciplinary insights and research that has led us to propose Echoes II. This project leverages the strong interdisciplinary advances made in our pilot project, and aims to make significant new contributions in TEL, and in the core

disciplines of the co-investigators. We will build on the close collaboration developed in ECHOES between researchers, special needs practitioners and teachers in the different disciplines. We have six partners: Edinburgh University with expertise in multimodal dialogue systems, developmental psychology, HCI and TEL; London University, with expertise in socio-linguistics, cognitive science, adaptive learning environments and artificial intelligence in education; Sussex University, with expertise in leading edge technologies to support learning and learner centred design methodologies; University of Wales Institute, Cardiff, with research and development experience with Reactive Colours and expertise in applied arts for education of children with autism; Dundee University, with expertise in accessibility research, augmentative and alternative communication, and computer based language development systems for children with disabilities, and Birmingham University with expertise in language communication, social interactions, child education, autism and TEL. The Sussex team have developed strong links with schools that cater for children with AS and are well placed to carry out participatory design activities. We will establish further collaborations with partners in education, practitioners and focus groups, teachers, parents as well as children who will participate in the studies proposed.

Contribution to knowledge: We have grounded our proposal in an interdisciplinary literature review and a comparison with the state-of-the-art in relevant competing projects both in the UK and abroad (ECHOES report). The ECHOES small project funding has allowed us to explore other disciplines, resolve theoretical conflicts, and develop a shared analytic and methodological framework within which to approach TEL tools for developing social skills in children and to embed those in the existing curriculum and educational practice at primary level. The proposed work is likely to have a deep and positive impact on current research in this field.

Research Teams and Project Management: There is a wealth of project management experience, for multi-site interdisciplinary projects, in this team (see individual CVs of the principal and co-investigators). We have developed a clear management structure, with built-in redundancy for robustness, and clear responsibilities at each site for delivering specific milestones. There are 2 main project leaders for both design/ research, and technology/ implementation who will collaboratively deliver on the overall project goals. The project management committee is comprised of the co-investigators and will meet every 4 months. Conflicts are decided by simple majority of this committee, with the PI having a deciding vote in the case of a tie. We will also appoint a project advisory committee, consisting of representatives from the teaching profession, TEL industry, and academia. The individual project personnel are of the highest expertise in the required fields, and have budgeted significant amounts of their time to deliver a successful collaborative project. Value for money is excellent, given the likely learning outcomes, scientific and technological impact, professional development, and communication activities proposed.

Contribution to Research Capacity Building: The proposed work involves researcher training, and training opportunities for teachers and carers. Continuing Professional Development is supported through the academic research and technology development, design and experimental studies and a research and dissemination workshop for practitioners, participants and researchers, to be run in year 3. We also propose 1 linked PhD scholarship to equip a new generation of researchers with interdisciplinary skills.

Communication, Knowledge Transfer, and Impact plans: The conceptual, methodological, technological, and other scientific advances made in ECHOES II will be communicated to 6 different audiences: academic researchers, developers in the TEL industry, teachers, parents, practitioners, and the general public. Communication with academics will take place through peer-reviewed international journals, conferences, and workshops, and the project website. Knowledge transfer to the TEL industry will take place via yearly ECHOES news-sheet mailings to the main players in the market, and invitations to visit project partners. Teachers, parents, practitioners and children will be engaged through ECHOES participatory design methods, and involvement in user studies, and subsequent debriefings. The Edinburgh University Press Office will disseminate project news to the national and international media for use by the general public. All ECHOES software will be released open source, under a GPL license at SourceForge. The resulting developer community will sustain the technology outputs after the lifetime of the project. This targeted communication strategy is planned to magnify and sustain the overall impacts of the project. Logs of data collected will be publicly available through the ESRC and the project website.