

# Embodiment as a means for Scaffolding Young Children's Social Skill Acquisition

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## ABSTRACT

In this paper, we discuss the notion of embodiment in the context of the ECHOES project, which aims at developing a multi-modal interactive environment for scaffolding young typically developing (TD) children and children with Asperger Syndrome (AS) in acquiring social interaction skills. Whilst, our approach to embodiment is in line with the current HCI trends, the pedagogical nature of ECHOES and the specific target users pose unusual challenges to the design and implementation of embodied interaction.

## Keywords

Embodiment, social interaction, autism, emergent narratives, modes of interaction

## INTRODUCTION

In the last decade, there has been an increased interest in the application of the *embodied interaction* paradigm in the design of interactive software systems [1]. In this context, embodiment does not only refer to the property of an artifact of being manifest in real-time and real-space, but it also denotes a “participative status” of the artifact, i.e. its presence in a specific situation where other phenomena and actors are situated as well. According to Dourish [1, p. 126]: “*Embodiment is the property of our engagement with the world that allows us to make it meaningful*” and “*Embodied Interaction is the creation, manipulation and sharing of meaning through engaged interaction with artifacts*”. This interpretation of embodiment, which has strongly influenced research in Human Computer Interaction (HCI), is at the core of the development of the ECHOES project.

In this paper, we describe ECHOES and its theoretical basis. Then, we outline the issues that arise in relation to the design of embodied interaction as a consequence of our ambition to help TD and AS children in acquiring socio-cognitive skills that transfer to the real world.

## THE ECHOES PROJECT

ECHOES is an interdisciplinary project whose main goal is to develop a technology-enhanced learning (TEL)

environment to support young TD and AS children between the ages of 5 and 7 years in exploring, acquiring and using social and communication skills. The project also aims at developing tools that would facilitate research in this area in ecologically valid situations, i.e. outside the laboratory, for example in the classroom.

ECHOES builds on recent activities in a number of traditionally independent research areas, each of which contributes an important insight into the design of the environment. *Psychology* provides crucial theoretical background and guidelines as to social interaction and current diagnoses and remediation practices in relation to Autism Spectrum Disorder (ASD). *HCI* and *Artificial Intelligence* provide sophisticated technologies for making the virtual world increasingly more tangible, explorable and readily manipulable, and finally *TEL* offers guidelines for underpinning technology design by real educational theory and practice in order to make it viable and educationally effective in the real world.

From a technological point of view, ECHOES integrates interactive white boards with eye-gaze tracking, facial expression and gesture recognition. The fusion of these different technologies is facilitated by a *reasoning engine* that selects the appropriate learning activities based on the assessment of the child within each learning activity and on their specific high-level learning objectives. The reasoning engine works on the basis of the *child model*, which incorporates static information about the child and knowledge about the skills that s/he dynamically has acquired during the interaction with the system.

## THEORETICAL BASIS FOR ECHOES

Four key theories of child development act as a theoretical framework for ECHOES and as the basis for its learning objectives: **Theory of mind** [2] explores children's ability to reason about the mental states of others; **Executive functioning** [3] investigates child's ability to initiate, sustain, shift from and inhibit/stop interactions or particular topics therein; **Central coherence** explores children's

ability to integrate pieces of information into coherent wholes, e.g. making sense of their own mind's activities and their ability to extract overall meaning from larger pieces of information [4] and to generalise newly learned behaviours to novel environments [5, 6]; **Inter-subjectivity** [7] investigates problems associated with "experiencing self" and "self-other" relations".

Together these theories offer an account of the possible cognitive *precursors* of social engagement. The precursors include:

1. **Imitation:** the ability to reproduce with some accuracy the actions (or vocalisations) of another person after having physically observed these actions.
2. **Dyadic relationships:** the ability to engage in a mutually regulated, reciprocal and harmonious interaction with another person. It relies on the ability to distinguish between conscious and unconscious agency.
3. **Joint attention (triadic relationship):** the ability to share attention with an adult concerning a third object or actor; it involves awareness of self, of others and of objects.
4. **Belief-desire reasoning:** the ability to reason about the beliefs of others; it is a crucial precondition to increasingly sophisticated reasoning (see 5 and 6).
5. **False belief reasoning:** the ability to understand that another person may hold a false belief about something; it is necessary to understand the subjectivity of the mind and is a precondition of goal-directed behaviours such as planning.
6. **Second-order belief attribution:** ability to judge one person's false belief about another person's true belief; it is a fundamental precondition of fully-fledged interactional engagement and communication.

These precursors guide the design of ECHOES' learning activities. Each activity corresponds to one precursor. A set of activities that are related to each other by theme or because they address a different aspect of the same precursor can be combined to form *narratives*. Each child will be presented with a set of activities related to the precursors which s/he may need to improve on or develop.

#### **EMBODIEMENT IN ECHOES**

Given the six precursors identified by the cognitive development research, embodiment and its emergence through children's interaction in and with their environment becomes central to ECHOES' ability to deliver appropriate support to children. It constitutes an essential tool in both the development of skills in relation to many such precursors and for manifesting the related skills through specific behaviours in different contexts. However, in contrast to many current approaches to the design of embodied interactions, ECHOES' faces unusual challenges that may impact the definition and use of embodiment within it. These challenges are defined by ECHOES' two main constraints: (1) the target population, which does not only consist of young children in a specific age range, but also children who vary in terms of their socio-cognitive

abilities, i.e. typically developing children and children with AS and (2) the fact that ECHOES is in essence a learning environment, i.e. it is driven by specific learning goals that need to be achieved within it as well as in the real world. Thus, any embodiment that is afforded by the environment needs to satisfy the cognitive requirements and aptitude of the individual children and to be in service of the learning objectives that are designed to accommodate such requirements and to enhance the child's aptitude.

We explore ECHOES' requirements in relation to embodiment both by drawing from theories of embodied social cognition [8, 9] in which the focus is on the embodiment of mental states and the impact that such embodiment has on cognition, and from HCI research in which the emphasis is on interactions, and the evolution thereof, between agents and objects in the external world. Of particular relevance to ECHOES is Williams et al.'s [10] distinction between three modes of interactions with objects: (1) **iconic**, i.e. literal, (2) **intrinsic**, i.e. based on the physical configuration of the objects, and (3) **instrumental**, i.e. that goes beyond the function for which an object was originally designed and which is based on the effects that the object can cause when employed in an atypical way. These different modes of interaction define the way in which people in general engage with the world and assign meaning to the objects within it. They are especially pertinent to people's development of social understanding and competence.

Young TD children will have the ability to engage in all three modes of interactions, but depending on their exact age may have a dominant preference for one mode over another. In particular, *pretend play* is crucial at the earlier stages in child's development. It often makes use of intrinsic and instrumental use of objects, e.g. the child might use a banana to pretend it is a telephone. An environment that exploits and builds on this mode of interaction needs to be able to interpret the meaning that the child assigns to a particular (set) of object(s), to represent it accordingly and to detect the child's acceptance of such an interpretation. As children get older, their ability to engage in all three modes of interactions will increase. They will become more aware of the conventions used in all those interactions and become better at explicitly discerning the literal, from the intrinsic, from the instrumental. Thus, an environment that builds on the three interaction modes in scaffolding the child in relation to the specific developmental precursors needs to be equipped with adequate interpretative and representational power to provide a coherent and meaningful experience to the child. In ECHOES, the learning activities form part of narratives, which are developed through the child's interacting with and acting on the objects within ECHOES, but whose emergence is guided by the ECHOES' specific learning objectives. Thus, if the child shifts between the three modes of interactions by exploring and exploiting different affordances [11] of the ECHOES' objects, ECHOES needs to be able to detect and accommodate these inter-mode

transitions in a way which preserves the coherence of the narrative and the success of the learning activities therein. Equally, when changing the modes of interactions to facilitate specific activities, ECHOES needs to do so in a way that avoids ambiguity as to the purpose of an activity, as to the identity of the agents within in and as to the believability of the world portrayed. For example, as part of acquiring skills needed for imitation, the child might be encouraged to engage in iconic interaction with the ECHOES' bubble activity and to explore the properties of bubbles (e.g. they are see-through, float in the air and pop). When the child achieves a certain level of skill, the next activity, within the same narrative, might be to engage the child in an imitation task whereby, say, a 'mischievous' bubble takes on the role of an agent and pops the other bubbles by 'intentionally' colliding with them. The *agency* of the mischievous bubble, which in this context refers to its intentional behaviour as well as its mischievous nature with all its affective implications, constitutes an essential part of its embodiment.

Avoiding ambiguity is particularly important in relation to scaffolding the experience of children with ASD, whose dominant preference will be of interacting in the iconic and, to an extent, in the intrinsic modes. Depending on their exact impairment, such children will have severe difficulties in engaging in pretend play and will almost certainly find it challenging, if not pointless, to combine the three modes. Thus, some children may find the mischievous bubble unacceptable and frighteningly unpredictable. Whilst it is one of ECHOES' aims to ease such children into using all three modes, the transitions between them will need to be more gradual than for TD children and the embodiment of the specific interactions may need to be achieved through more literal means. For example, instead of a mischievous bubble, ECHOES may need to introduce a humanoid virtual agent to demonstrate the task to the child. Furthermore, the embodiment, including any intentions and affective characteristics of the agents in the environment, may need to be based on impoverished sets of attributes, as many autistic children do not cope well with certain stimuli or combinations thereof, for example with specific sounds or colours.

In the context of ECHOES, embodiment serves as a learning tool through which children can both observe specific behaviours and manifest their own behaviours. Children can act on the environment and observe the consequences of their actions. Moreover, embodiment in ECHOES needs to provide the means through which the child's progress can be assessed and advanced.

#### **FROM INTERACTION TO THE "NEGOTIATION LOOP"**

Given ECHOES' pedagogic nature, we are not satisfied with creating an environment that merely provides entertainment to the users. Our approach to both scaffolding children's exploration of social skills and to assessing their abilities is to engage children in a form of *dialogue* with the system, through which they *negotiate* the

meaning of the objects that populate ECHOES' world and agree on how to progress the interaction further. We refer to this collaborative interaction between the system and its users as the "**negotiation loop**". ECHOES and the child will flexibly and interchangeably play two different roles: sometimes, ECHOES will be the initiator in suggesting the meaning of an object and possible story lines around it; other times, it will be the child who will assign a meaning to an object and ECHOES will attempt to capture that meaning and react appropriately. The system supports this negotiation loop by providing the user with a *repertoire* of loosely defined shapes that can be turned into concrete objects and/or can *morph* into one another depending on the actions that the child performs on them. For example, an underspecified blob can turn into a ball, a bubble, a drop of water, a push-button, and so on. This allows ECHOES to provide an imaginative playground for children by taking advantage of the natural visual affordances of ordinary shapes [11]. The **morphing** of one object into another is the result of the negotiation between ECHOES and the child. When it is the child who suggests a meaning for an object, for example by poking the underspecified blob, ECHOES interprets the child's action based on a set of modalities that are supposed to be the most indicative of the meaning intended by the child. These might include the child's style of touch (e.g. poking as opposed to slapping), their vocalisations (e.g. a surprise noise or a laugh), their eye gaze (the length of gaze fixation on the object) etc. The result is an ECHOES' action that is coherent with the child's intended meaning, e.g. if the child pokes the blob, it is turned into a bubble that pops; if the child slaps the blob, it is turned into a push-button. In other activities, it is ECHOES that explicitly suggests a meaning for a specific object, the expectation being that the child will understand and accept this meaning by acting in accordance with the object's properties. Thus, ECHOES facilitates a two-fold interaction between itself and the child who can flexibly take the lead or leave it up to the system to progress the narrative. Facilitating such interaction allows us both to explore and assess the cognitive abilities of children and to progress them towards more challenging tasks.

Thanks to morphing and the negotiation loop, narratives in ECHOES can *emerge* from the interaction between the system and the user rather than being fully authored *a priori*. **Emergent narratives** [12] have been used in the development of virtual storytelling system as means for bringing together the freedom of interaction afforded by virtual environments and the structure required by telling an engaging story. Similarly, through the mechanism of emergent narratives, we are planning to reconcile the exploratory nature of ECHOES with its pedagogical goals.

#### **CONCLUSION AND FURTHER WORK**

The ECHOES project presents a number of challenges, which are not only related to the actual implementation of the different levels of embodiments, but also to the development of the ECHOES' child model and the action

engine, both of which lie at the core of the system. The three modes of interactions proposed by Williams et al. [10] provide a good starting point for a design of embodied interaction for young children who differ from one another in terms of their cognitive abilities. The distinction between the iconic, the intrinsic and the instrumental modes is consistent with the developmental precursors identified in the cognitive development literature as essential for the acquisition of social interaction and communication skills. Whilst the HCI and the psychology research paradigms tackle different issues related to interaction and for different purposes, both paradigms independently highlight the importance of embodiment in any successful interaction. In addition, they emphasise that embodiment is not limited to the physical presence of objects and agents in the world, but it emerges through our social behaviours and extends to the agents mental states [13]. In the ECHOES project, which is at its early stage, we will pursue the two paradigms hand in hand in order to develop a system capable of delivering appropriate intervention for children. In particular, we are developing the basic elements of ECHOES narratives that will facilitate the emergence of the mixed initiative interaction between the system and the child. We have also formulated a basic framework for building the narratives and, with other teams in the project, we are working on implementing it and evaluating it formatively. We are involving children in participatory design workshops (the Sussex team) to inform the development of the narrative themes as well as repositories of objects, agents and actions that children might want to perform on the objects and with the agents. We will report the results of these efforts in due course.

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#### REFERENCES

1. Dourish, P. *Where the action is: The foundations of embodied interaction*. MIT Press, Cambridge MA, 2001.
2. Baron-Cohen, S. *Mindblindness*. MIT Press, Cambridge MA, 1995.
3. Denkla, M. B. A theory and model of executive function: A neuropsychological perspective. In G.R. Lyon and N.A. Krasnegor (Eds.), *Attention, memory and executive function*. P.H. Brookes, Baltimore, MD, 263-278
4. Happe, F., and Frith, U. The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 36(1), 2006, 5-25.
5. Mirenda, P.L., and Donnellan, A. M. Issues in Curriculum Development. In D. J. Cohen, A. M. Donnellan and R. Paul (Eds.), *Handbook of autism and pervasive developmental disorders*. J. Wiley and Sons, New York NY, 1987.
6. Plaisted, K.C. Reduced generalization: An alternative to weak central coherence. In: Burack, J.A., Charman, A., Yirmiya, N. & Zelazo, P.R. Eds. *Development and Autism: Perspectives from theory and research*. Lawrence Erlbaum Associates, New Jersey, 2001.
7. Hobson, P. *The Cradle of Thought. Exploring the Origins of Thinking*. Oxford University Press, 2004.
8. Goldman A., and de Vignemont F. Is social cognition embodied? *Trends in Cognitive Sciences*, 13(4), 2009, 154-159.
9. Wilson, M. Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9 (4), 2002, 625-636.
10. Williams, A., Kabish E., and Dourish, P. From Interaction to Participation: Configuring Space through Embodied Interaction. *Proceedings of International Conference on Ubiquitous Computing 2005* (Tokyo, Japan), 287-304.
11. Norman, D. A. *Psychology of Everyday Things*. Basic Books, 1988.
12. Louchart, S., and Aylett, R.S. Narrative Theory and Emergent Interactive Narrative. *International Journal of Continuing Engineering Education and Life-long Learning* 14, 6 (2004), 506-518.
13. Butterworth G. Theory of mind and the facts of embodiment. In Lewis, C. and Mitchell P. *Origins and Development*. Psychology Press, 1994.