Language Learning with Mobile Augmented Reality and Artificial Intelligence for Children with Autism Spectrum Disorder

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ABSTRACT

Augmented Reality has gained popularity among special needs communities. The flexibility and the advanced capabilities of this technology, empowered with AI, are opening new opportunities for further research in the area of digitally-aided language interventions for children with ASD. The goal of this research is to investigate and develop new knowledge tools to support language learning in children with ASD. The research methodology would be both qualitative and quantitative, using interviews, participatory design, and observations. Initially, this project will define the theoretical and existing applications of adaptive AR interventions for children with autism. A preliminary investigation has been conducted, suggesting promising results that can shed a light on the opportunities offered by AR and AI for language learning. In the next phase, we will design and develop a novel adaptive mobile AR application based on activities like workshops and participatory design, followed by systematic empirical evaluations of the proposed solution.

CCS CONCEPTS

• **Human-Computer Interaction (HCI)**; • **Human-Centered Computing**; • **Empirical Studies in HCI**;

KEYWORDS

Augmented Reality, Artificial Intelligence, Language Learning, Autism Spectrum Disorder, Children

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1 RESEARCH TOPIC

1.1 Context and Motivation

Technology has become an important component in language acquisition pedagogy [16], thanks to the rapid advancement of digital innovation in the recent decade. Educators recognized that utilizing Computer Assisted Language Learning (CALL) applications can be convenient to create both independent and collaborative learning environments, as well as providing students with language learning experiences as they move through the various stages of language acquisition [15]. The manner of engagement with learning experiences is evolving; instead of using keyboards and mice to interact with on-screen content, students can now use their entire body and touch-screen based interactions to access educational content that appears to exist in the real world - as possible through augmented reality (AR), offering children with learning opportunities through immersive simulations and instructive games. Yet, there is limited research on using AR with special needs users. Most studies only involve children without intellectual disabilities and learning impairments.

Among the various forms of intellectual disabilities, autism is becoming more common in children as a result of several biopsychosocial and environmental factors, as well as changes in diagnostic criteria. A variety of interventions have been proposed to cure autism. Among these are treatments which are efficiently carried out by computer-based interventions (CBI). In particular, CBIs with mobile technology improve the learning of children on the autism spectrum [21]. Nontheless, few studies investigate the affordances of mobile AR to support children with ASD in learning aspects of languages. On the other hand, Evidence based research shows that AR supports attentional behaviour, fosters emotional and social skills, and improves communication abilities in children with autism [19], which motivates our work. In addition, a growing body of research has discovered basic variations in how children with autism map and generalise word–picture relationships [22], which is still widely unexplored.

1.2 Related Work

Autism spectrum disorder (ASD), according to the American Psychiatric Association [3], is a neurodevelopmental disorder marked by establishing social skills and symbolic communication deficits, and interfering repetitive behavior. Severe impairments in language acquisition and usage are a common characteristic of children diagnosed with ASD. Specifically, 80% of individuals with ASD aged 5-years and younger are non-verbal [6], and 30% are minimally verbal at 9-years [2]. During the last decade there has been a growing interest in AR; the development of interactive technologies in the fields of Human-Computer Interaction (HCI) and Child-Computer Interaction (CCI) has been driven by a general tendency to embrace developing and interactive technologies, creating applications that address end users' requirements and needs [9].

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AR is an innovative technology that offers an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory. Technically AR is a system [4] with the following three main characteristics: 1) combines real and virtual world, 2) interactive in real time and 3) registered in 3D. AR use has started gaining momentum in learning and educational settings [23], offering new approaches to engage with the actual world, and can produce experiences that are not achievable in either a completely real or virtual environment. Several learning fields have been explored by AR applications, such as science, math, biology and the production of literature and poetry [5, 7, 17]. Yet, few studies investigate how mobile AR can facilitate language learning activities for children with ASD.

On the other hand, findings from these studies suggest positive results in terms of learning outcomes. For example, Khowaja et al. [13] proposed MARVoc, an early-stage prototype of mobile AR application to facilitate vocabulary learning in children with ASD. On the same line, Tang et al. [24] presented a preliminary study on a mobile vocabulary-learning application empowered with AR and AI capabilities for Chinese children with ASD, leading to positive outcomes in terms of vocabulary acquisition. Yet, many of the works in the literature are in a preliminary stage, and there is a lack of research and design around adaptive learning experience that leverage AI potential to support children with ASD; In addition, to the best of our knowledge, word-pictures association with AR for children with ASD is largely unexplored.

1.3 Research questions

The presented research addresses the following research questions:

- **RQ 1** How can we support children with ASD in language learning activities using Augmented Reality and Artificial Intelligence?
  - **SQ 1.1** What are the affordances of augmented reality for language learning in children with ASD?
  - **SQ 1.2** How can we design adaptive experiences with augmented reality that can facilitate language learning activities for children with ASD?
  - **SQ 1.3** How can we properly evaluate the effectiveness of our proposed solution?
- **RQ 2** How do children with ASD interact with mobile technology and augmented reality?
  - **SQ 2.1** How domain experts and parents/caregivers of children with ASD perceive the potential of mobile technology and augmented reality for language learning activities?
- **RQ 3** What are the ethical considerations to take into account when designing language learning activities with Augmented Reality for children with ASD?

2 RESEARCH METHODS

Based on the context of our research, the main methods identified are: Surveys supported by semi-structured interviews [18], Participatory Design [20], Systematic Literature Review [14], Design Science [8]. Considering that the users are at the centre of our research, design and development process, a User Centered Design (UCD) Research Approach [1] is a valid approach for our project. UCD is achieved by interacting directly to the end users (and their parents/caregivers in our case) at key points in the project to make sure the solution will deliver upon their requirements (co-design process). Following that, we will perform iterative cycles along the whole study process to assess the effectiveness of the whole research. Being already aware of the problem in question, we will begin to interact directly with the stakeholders to collect requirements, investigating our users' needs and what are the affordances of AR for language learning. Each of the steps defined in the flow below (Figure 1) represents one of the different stages of our iterative cycles. At the current stage of our research, we are transitioning from the first step to the second one.

3 THE WORK SO FAR

The proposed research is part of the MSCA ITN Early Language Development in the Digital Age (e-LADDA)[1] project, which aims to determine if the new and intuitive interactions provided by digital tools have a beneficial or negative impact on young children's language development and results. This PhD project targets pre-school children diagnosed with ASD to support them in language learning activities through the design and development of a novel mobile AR application that helps in the vocabulary acquisition and adaptive label generalization to real world objects. The project started in November 2021 and is expected to be completed due November 2024. The presented research work is funded by SpongeUK, a digital learning company which is among the beneficiaries of the e-LADDA project. So far, a research project proposal covering the whole duration of the PhD project has been delivered to the Norwegian University of Science and Technology. We have done an initial review of the state of the art and of available research methods to investigate the problem.

A Systematic Literature Review (SLR) is being conducted according to Kitchenham [14] guidelines, to establish a theoretical grasp of the research topic and related research and activities, to identify the research methods used in relevant studies, the various methodologies for teaching vocabulary and association of word-pictures to real world objects for children with ASD, what technological applications have been designed and developed as a solution, analyzing the related methodologies, the different interaction paradigms and AI capabilities for adaptive learning (**SQ 1.2**).

Anchoring of the findings from the preliminary investigation of the literature was supported by a small-scale exploratory study, surveying three domain experts and parents of children with ASD (**RQ 1**, **SQ 2.1**) with semi-structured interviews as a data generation method, to gather insights on the affordances and challenges of mobile AR for language learning in children with ASD. The interviews were conducted by video and audio recording with the consent of the interviewees, in addition to taking field notes after the interviews.

Our analysis yielded some findings that are consistent with what is found in the literature (**SQ 1.1**); AR's portability and context sensitivity make this innovative technology ideal for all educational

[1] https://www.ntnu.edu/e-ladda

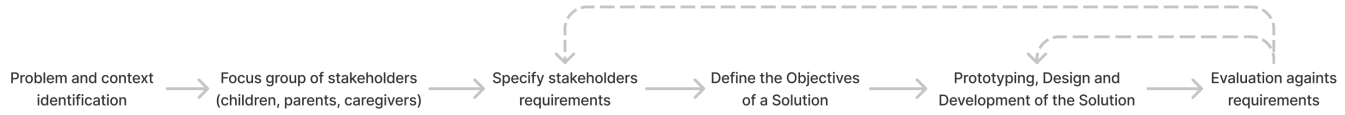

Figure 1: UCD iterative flow

environments, from elementary school to higher university levels. Studies in the literature show how applications developed for mobile technologies help children with ASD to communicate, by expressing needs through pictures. Further evidence shows how mobile technology can teach children with ASD about emotions through various facial expressions, as well as to develop their social skills. AR offers several benefits in contextualising language learning activities, based on real-world scenarios [10, 12], increasing the collaboration amongst students and the ability to remember how to execute specific tasks [11]. Moreover, findings from our investigation indicate that mobile technologies and AR have a low risk of stigmatization in the children and they improve children autonomy and self-esteem. On the other hand, there are some challenges such as lack of abstraction skills when interacting with mobile applications, and decrease in focus and attention when there is a lack of a proper design strategy of mobile AR applications. In order to generalize the results obtained a larger sample should be involved, possibly through a case study, and involving the children as well, but as a preliminary study of the research presented in this paper it highlights the potential of mobile AR in our research domain.

4 NEXT STEPS

In our research agenda we foresee to design and implement systematic digital interventions by means of a novel mobile AR application, with multiple iterations to refine and improve our initial designs, leveraging the outputs resulting from a Participatory Design, involving stakeholders (parents, psychologists, and psycholinguists). Inputs provided by the participatory design with the participants will serve as insights and guidelines (**RQ 2**, **SQ 2.1**, **RQ 3**) for the next step of our research agenda, consisting of a well-structured software engineering process. In the next phase we will identify the most appropriate approach to evaluate our solution (**SQ 1.3**) and implement it according to software engineering best practices and a further evaluation will be conducted, based on the iterative cycles discussed in Section 2. We expect to work further with the research questions, in order to refine them, and the choice of the adequate research methods that we identified, by leveraging further findings from the SLR, an in-depth analysis of larger scale investigation of interviews, workshops, participatory design and the feedback that we would receive at the Doctoral Consortium.

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