Opportunities and Challenges of Using XR to Support Children with Dyscalculia in Mathematical Training

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Learning disabilities such as dyscalculia (or number blindness) can profoundly impact a child's educational journey, self-confidence, and participation in academic and social contexts. In an upcoming project, we aim to explore how Extended Reality (XR) technologies can support children with dyscalculia in training fundamental mathematical skills. As an initial step, we will discuss possible opportunities, challenges, and ethical concerns.

CCS Concepts: • **Do Not Use This Code → Generate the Correct Terms for Your Paper**; *Generate the Correct Terms for Your Paper*; Generate the Correct Terms for Your Paper; Generate the Correct Terms for Your Paper.

Additional Key Words and Phrases: Dyscalculia, AR, child, HCI

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1 Introduction

Basic mathematical skills are essential for various aspects of everyday life and a wide range of professional fields. Mathematics fosters critical thinking and problem-solving skills, vital for decision-making and analytical reasoning. It is crucial for STEM (Science, Technology, Engineering, and Mathematics) careers and plays a significant role in economics and finance.

Unfortunately, many children fall behind due to math learning disabilities, such as dyscalculia, i.e. the inability to represent and comprehend numbers conventionally [19]. Dyscalculia affects 3 to 6% of all children and significantly impairs the children's ability to grasp mathematical concepts [18]. Compared to dyslexia, dyscalculia remains significantly under-researched [13], with studies suggesting it is mentioned up to 14 times less often than dyslexia in academic literature (PubMed search by S.R. Snodgrass). Within the Child-Computer Interaction (CCI) community, efforts have been made to support math learning through interactive technologies [2, 3, 6, 11], but targeted research on dyscalculia remains sparse. This disparity highlights the need for more focused research on dyscalculia.

Our preliminary investigation indicates a lack of effective digital tools and diagnostic instruments in Danish schools to support children with dyscalculia. We propose to investige how Extended Reality (XR) can be leveraged to design

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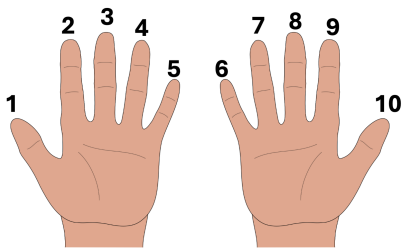
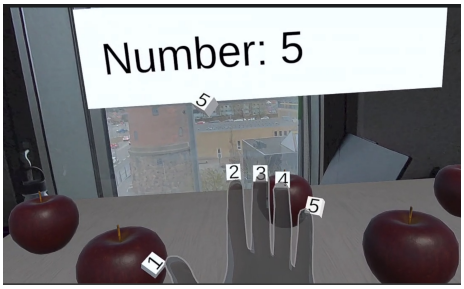
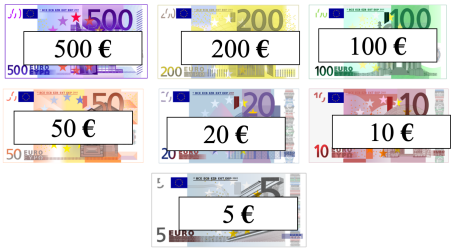
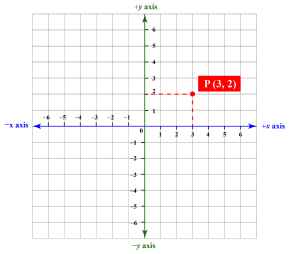
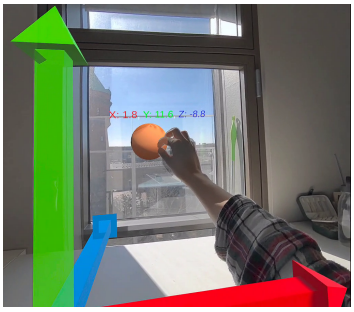
#	Paper-based Math Exercises	Augmented Reality Representation
1		
2		
3		

Table 1. Comparison between real-world math exercises and their augmented reality representations.

engaging, adaptive, and embodied training experiences that help children with dyscalculia train fundamental math skills.

XR technologies, particularly Augmented Reality (AR), provide unique affordances for creating targeted training scenarios. They enable the seamless integration of digital content with the physical world, offering opportunities for contextual training, embodied interaction, and multisensory feedback. The ability to extend the real world with digital information anchored in the physical space opens new opportunities to augment existing training materials or develop entirely new intervention tools [14]. These characteristics make AR a promising training technology medium for children with dyscalculia, who often require individualized, engaging, and repetitive practice in mathematical tasks. Moreover, recent studies indicate that AR can enhance motivation and positive attitudes toward academic subjects [9, 16, 17].

Despite its promise, AR in educational contexts raises critical ethical concerns, particularly when children are involved [8, 10, 20]. Although there is limited evidence regarding any potential harms from short exposure to XR in children under 14 years under supervision [4], we are aware of that additional research is required to understand the effects of long training sessions, motion sickness, and fatigue (mental and physical). As is clear with both classic [7] and recent literature [15], symptoms such as nausea, dizziness, and fatigue, arising from factors like sensory discrepancies between real and virtual movements, latency, graphic quality, and individual susceptibility, still remains a problem with this technology. While major technology companies drive development, ethical considerations are evidently lagging behind [12]. The majority of XR experiences are designed to run on a very specific hardware [1], but once a headset is no longer supported, the dedicated experience also disappear with it, unless they are continuously updated to move to newer systems. So, big tech (e.g. Meta, HTC, Microsoft, and Apple [5]) is the gatekeeper when it comes to deciding what gets to be kept and what gets lost within the XR community.

2 Examples of Applications

Our initial exploration in the field of mathematical training in XR for children with dyscalculia include three technical scenarios: (1) a finger-counting interface that enables dynamic number manipulation; (2) a tool that uses image processing to recognize physical currency and treat it as an interactive manipulative; and (3) a spatial reasoning experience that anchors a Cartesian coordinate system to real-world furniture for in-situ interaction. See Table 1 for a comparison of these examples.

3 Workshop Position Statement

We wish to participate in this workshop because we are embarking into a project focused on investigating how XR technologies can support children with dyscalculia in training core mathematical skills. Participating in this workshop will help us critically reflect on our early concepts and better understand the broader landscape of opportunities and challenges in this domain.

We can contribute with a specific field of application for XR technologies, namely mathematics training in children with dyscalculia. While our project is in its initial stages, we bring some early technical prototypes and theoretical insights. Although our investigation so far are theoretical and technical, we believe we can also contribute with examples of prototypes.

Through the workshop, we hope to connect with colleagues exploring the challenges, opportunities, and ethical dimensions of XR technologies for children. We are also highly interested in taking part in lessons learned from the IDC community, as well as getting feedback on our initial considerations.

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