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Learning to work together: Designing a multi-user virtual reality game for social collaboration and perspective-taking for children with autism

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ABSTRACT

Children with Autism Spectrum Disorders (ASD) find it difficult to engage in reciprocal, shared behaviours and technology could be particularly helpful in supporting children's motivations and skills in this area. Designing educational technologies for children with ASD requires the integration of a complex range of factors including pedagogical and cognitive theories; the affordances of the technology; and the real-world contexts of use. This paper illustrates how these factors informed the design of a novel collaborative virtual reality environment (CVE) for supporting communicative perspective-taking skills for high-functioning children with ASD. Findings from a small-scale study involving eight typically developing (TD) children (aged 8 years) and six children with ASD (verbal mental age 9 years) are also reported. Children with ASD were supported to be reciprocal and collaborative in their responses, suggesting that this CVE could form the basis for a useful technology-based educational intervention.

1. Introduction

Autism Spectrum Disorder (ASD) is characterised by pervasive difficulties in social interaction and communication, and a restricted range of interests and behaviours [1]. Approximately 1 in every 100 children in the UK [2] is diagnosed with an ASD; with around 700,000 people with autism living in the UK [3]. The economic cost to society of supporting individuals with autism and their families is significant with the estimated annual cost at £3.1 billion in the UK, and $61 billion in the US [4]. Consequently, finding ways to more effectively educate and support individuals with autism to improve outcomes, and decrease reliance on specialist provision, remains a research priority for individuals and their families [5]. Recent reviews of the research evidence for technologies for autism have underscored both the interest in, and continued potential of, developing and applying technologies for addressing this need (e.g. [6–11]). Given the significant costs involved in providing specialist provision for autism, it has also been emphasised that technologies may offer a cost-effective and accessible means of assessing, and targeting, children's learning needs [12,13,8].

This paper applies a conceptual model of learner-centred design [14] to illustrate a novel collaborative virtual environment (CVE) for children with autism, designed with teacher input to support collaboration and reciprocity in behaviour and communication. A preliminary observational study is then reported that explores whether the CVE supported these behaviours between pairs of age-matched children with ASD, and pairs of typically developing children. The study suggests that children with ASD were supported by the structuring of the CVE-based tasks, and teacher facilitation, to collaborate and communicate in a reciprocal way, although they less collaborative and task-focused overall compared to the typically developing children. The following sections describe the background and rationale for the design and development of the CVE before presenting the methods and detailed results of the small-scale study.

2. Background

2.1. Designing technologies for children with autism

The number of peer-reviewed papers on technology and autism has risen substantially since 2001 [15] and evidence from a recent meta-analysis examining learning outcomes for children with autism in technology-based interventions showed positive results [13]. These reviews call for further research to explore

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the benefits of technology-based educational intervention more widely and to strengthen the evidence base. Notably, Ploog et al. [15] concluded that: "*Properly designed* CAT (computer-assisted technologies) programs may be advantageous in helping children with ASD attain skills for increased adaptive functioning. *A problem that often arises is that the majority of the available programs have not been developed specifically for this population*" (p. 319; emphasis added). This leads to the question: what does it mean for a technology to be specifically designed for children on the autism spectrum? Researchers have provided some insights although the following suggestions are by no means exhaustive or definitive.

Firstly, there seems to be agreement that educational technologies for autism should be designed for supporting learning in the core areas of difficulty characteristic of an ASD diagnosis i.e. social communication and interactions. For example, technology-based research has targeted (*inter alia*) social conversation, language, play, and adaptive behaviours [15,11]. Understanding, and focusing on, the core difficulties of autism as the basis for designing effective educational curricula is not confined to technology-based learning approaches, and is recognised as best practice in autism education generally [16–20].

Secondly, the value and importance of user-centred design has been recognised, with researchers often incorporating the views of parents, practitioners and children with autism into the development of technology-enhanced learning (TEL) environments for autism (e.g. [21–27]). The emphasis on user-involvement is not specific to autism but reflects a wider understanding about the ethical and practical advantages of gaining insights from the intended user population in technology design (e.g. [28–30]). Nevertheless, there are valuable discussions about the extent to which the methods that are used to involve users and seek their views need to be adapted to accommodate autism-specific characteristics and communication strengths/preferences. For example, when involving children with autism, researchers have successfully used more visual and structured methods and materials, and provided concrete examples to initiate and prompt ideas rather than relying on abstract concepts for discussion [31–33].

Thirdly, there is increasing awareness about the need to consider the situated context of use in which the learning is intended to take place; in other words, to move away from a "technologically determinist perspective" [34, p. 7] towards the development and implementation of technologies in the places where people are actually going to want to use them i.e. in homes and schools (e.g. [35–38]). It is important to involve members from the autism community in order to evolve a more ethical, informed and situated approach to research [5,39], and so interdisciplinary teams are essential [40,27]. Consequently, there is a need for researchers to work much more closely with schools to develop meaningful and context-appropriate ways of supporting the learning of children with ASD [41]. Therefore, while there are non-autism-specific as well as non-technology-specific principles that can be applied to designing technologies for autism, it is also crucial to be informed by a good understanding of autism in order to decide whether there are specific features that need to be considered to more effectively support children's learning (cf. [18]).

2.2. Theory, Technology and Thoughts (3T): conceptual approach to the learner-centred design of technologies for autism

Parsons and Cobb [14] argue that designing educational technologies for autism is complex territory, requiring consideration and integration of a range of factors. They propose a "triple-decker sandwich" (p. 421) model of learner-centred design for autism focusing on Theory, Technologies and Thoughts (3T), as a way of making explicit the many design decisions and influences that impact on how educational technologies are developed. The authors argue that the sandwich metaphor makes sense because only by bringing all three layers together can an effective product (sandwich) be made to support successful learning outcomes for children. The 3T model is applied below to illustrate the design decisions involved in the creation of a CVE called *Block Challenge*. This was one of the prototypes produced in the COSPATIAL project which was funded by the European Commission FP7 Programme to develop collaborative technologies to support the engagement and communication of children with autism in the classroom [23,42]. Inspiration for the 3T model came from early scoping of the field and the identification of "best practice" features of technology design for supporting the learning of children with autism [26]; the 3T model was further refined and clarified through the development of the *Block Challenge* prototype [14].

The core aspects of the 3T model described by Parsons and Cobb [14] for designing educational technologies for autism are:

1. *Theory*—the top-down disciplinary theories that are used to inform the development of educational tasks;
2. *Technologies*—the specific affordances of the technology/ies developed and applied for supporting learning and interaction; and
3. *Thoughts*—the grounded, bottom-up influences of the intended context(s) of use and the perspectives of the target users (e.g. children, parents, teachers, other professionals).

2.3. Illustrating the 3T model approach in practice

In terms of *Theory* the development of *Block Challenge* drew upon constructivist theories of learning which emphasise the importance of learners working together on tasks and being scaffolded in their learning via peers and teachers. There is good evidence from technology-based (e.g. [43]) and non-technology-based research [44–46] about the value of such pedagogical approaches for promoting good learning outcomes for children, including those with special educational needs (SEN). There is also good evidence that peer interactions can promote positive social outcomes for children with autism when paired with typically developing children [47,48] and other children with autism [49].

Additionally, theories concerning the needs of autistic learners were helpful regarding the best practice requirement for focusing on core difficulties as targets for educational intervention (noted above); in this case, the socio-cognitive difficulties experienced by children on the autism spectrum relating specifically to collaboration and reciprocity in behaviour and communication [50,51]. In this context, Bauminger [52–54] demonstrated that supporting children with autism to focus on both thinking and behaviour, and to reflect on their experiences and observations with peer or teacher facilitation (i.e. scaffolding), can effectively support social understanding. Thus, we drew across these theories to specify that the prototype design needed to (a) target core difficulties in reciprocal social communication and interaction; (b) support children's thinking and behaviour; (c) scaffold children's interactions; and (d) enable children to work on tasks with each other in an engaging way.

The affordances of the *Technology*, therefore, needed to be in alignment with this theoretically-informed approach. Given the focus on collaboration in the project, we selected technologies that could only be used by more than one person interacting with them concurrently: CVEs and Shared Active Surfaces (SAS). The prototype discussed here was a CVE and so the SAS will not be discussed further (but see [55,56], for more details). The bespoke CVE was a 3-D virtual space, which could be navigated in real time, and allowed more than one user to interact with the scene and each other. The focus on collaborative technology adds