Development of an immersive Virtual Reality (VR) system to improve the quality of rehabilitation for paediatric Ataxia Telangiectasia (A-T) patients.

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ABSTRACT

Ataxia-Telangiectasia (A-T) is a rare and severe genetic disorder (approximately 1 in 300,000 live births (A-T Society, 2014)) that is paired with decelerated production of protein within the body. As a result, several bodily functions are damaged including but not limited to, a diminished immune system, poor upper and lower limb functionality, and heightened risk of malignancy of the blood. The research team have been investigating whether virtual reality (VR) equipment and its immersive environments can be used as a form of cognitive and physical therapy to reduce the rate of muscle degradation and improve mental wellbeing for paediatric A-T patients.

1. INTRODUCTION

In the UK there are currently only two centres that offer patient centred care for Ataxia-Telangiectasia (A-T). As a result, access to care can be complex and costly for most patients. Review of a patient condition will be hold on an annual/bi-annual basis. Consequently, there can be a time delay during which no support or treatment is offered to the patient. We therefore envision the use of Virtual Reality (VR) as an easily accessible solution to maintain patients engaged and entertained while at the same time slowing down the deterioration of physical functions via the gamification of rehabilitation. As such an investigation into whether systems based on an around Virtual Reality technologies could provide an engaging and safe environment for A-T patients whilst also improving their physical and mental wellbeing was proposed. Following interviews with parents of A-T patients, the project's consultant clinical geneticist and an analysis of published papers, it was noted that regular physiotherapy is recommended for all A-T patients to reduce the rate of muscle degradation (Unes et al. 2021). The integration of the VR system will provide a unique opportunity for A-T patients to conduct their physiotherapy through an immersive and interactive environment. Complete with mini-games and cooperative gameplay we intend to improve patient wellbeing and engagement with physiotherapy activities. To create this, a multi-disciplinary research team of academics, industry professionals and clinicians have collaborated to design and prototype a solution that is optimised for patient use.

2. METHODS

The research team is investigating the use of VR as a form of motor and cognitive therapy for 5–16-year-old Ataxia Telangiectasia patients, to improve to their therapy experience and quality of life. A patient, carer and public involvement and engagement (PCPIE) group was setup for regular meetings aimed to obtain feedback on a custom-made set of environments used in combination with hardware developed. Before patients use any VR equipment, a four-stage baseline test is used to assess their gait, grip and cognitive ability. Tests include the Box and Block test and Action Research Arm Test. Baseline testing will also be repeated at the end of the study to evaluate if any improvement has been made. Patients will then be gradually introduced to VR and a 360°

frictionless treadmill, combined with a rehabilitation frame (Figure 1) and supportive hoist via a four-phase induction process.

Figure 1 *Virtualizer Elite 2 - A 360* Frictionless Treadmill (Cyberith, n.d)*

Once fully inducted, patients will be required to complete a variety of tasks within the VR environment allowing the research team to gather quantitative data on their gait, motor, and cognitive skills. Using a mixed method approach through the NASA-TLX and PACES-S scales, the research team will be collecting engagement data before and after sessions are conducted to evaluate whether the use of the equipment has improved patient wellbeing. We believe this research could lead to a significant improvement in patient motivation and enjoyment whilst pro-actively decelerating muscle and cognitive degradation through an easy-to-use, accessible, and interactive experience.

3. RESULTS

The custom-built environment, modelled in Gravity Sketch, programmed in Unity and developed alongside clinical members of the research team contains seven bespoke mini games based on real life activities that participants wouldn't normally be able to do, each increase in difficulty and range of movements. For example, game one, a linear buzz wire, requires the player to move a tool from left to right without touching the wire. This game requires lateral hip and arm movement and some rotational wrist movement. Game 6, is a variant of game one, requiring 120° rotational hip and wrist movement, with vertical arm movement. Each game can be adjusted by the 'assessor' to motivate/challenge players, such as reducing the time limit per game or adding additional objectives. The environment, paired with the 360° VR treadmill intends to provide upright support, aiding the user to walk naturally and build lower body strength. The solution aims to improve physical and mental wellbeing and provide accessible care. A mock-up of the intended VR environment (Figure 2) and a recorded demonstration video (Breedon et al., 2023) were used to exhibit a proof of concept to parents and clinicians at the A-T society family weekend event and various PCPIE group meetings. During the event the research team was provided with the opportunity to demonstrate the environment to two adolescent A-T patients by putting them in a VR headset, set in the mock up environment. The team identified a selection of critical design needs for the VR headset and its associating equipment that it is not truly inclusive for a disabled user. For example, whilst at the event it was noticed that the weight of the headset influenced the user's ability to hold their head up and look around the environment. Additionally, observations of the user's ability to grip the controller, press buttons and complete specific movement action was conducted. Movements were often sporadic with limited control over movements in both arm/hand movement. Further exploration will be conducted into alternative, inclusive methods of game control, including but not limited to; utilising hand tracking technology, integrating custom-made 3D printed controller grips, full body tracking through infra-red sensors and integration of smart textiles (Lugoda et al., 2022).

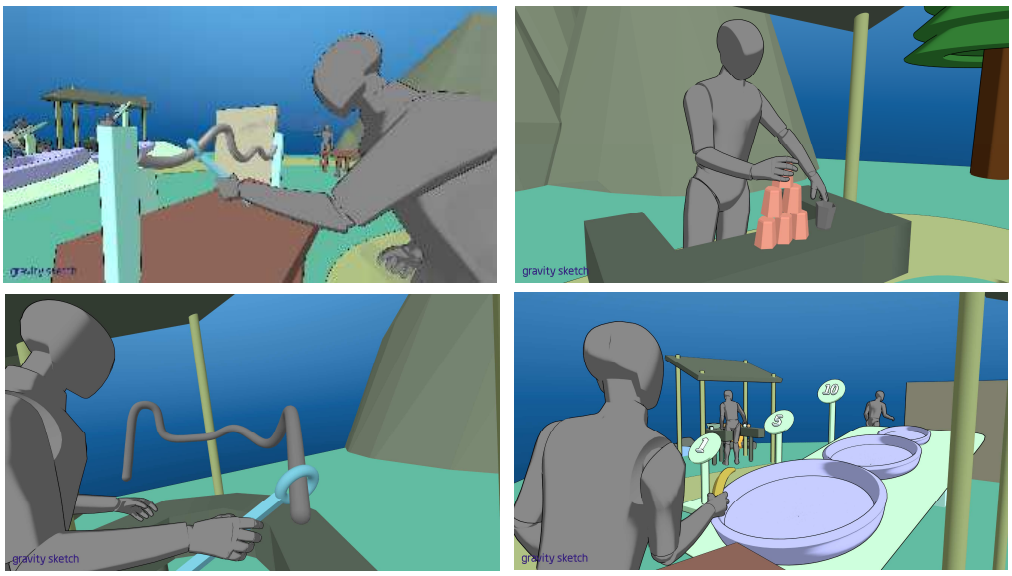

Figure 2 *Proof of concept examples developed during the pump priming phase (Breedon et al., 2023)*

4. DISCUSSION

Virtual Reality is becoming prominent within the UK medical sector, especially within rehabilitation (Mercer and Milliken, 2024; Morgan, 2024). However, cost and accessibility are some key limiting factors that could impact its true potential. Through our intended research study, we aim to establish a variety of adjustments to the VR equipment and software to make it more inclusive to further benefit A-T patients. For instance, we intend to improve social interaction between patients by adding multiplayer gameplay and in-game competitions but also add in-game tracking for clinicians to assess patient gameplay to provide live feedback from clinical locations.

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