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Factors influencing virtual reality use in paediatric acquired brain injury upper limb rehabilitation: a qualitative study

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ABSTRACT

Objective Upper limb movement difficulties in children with acquired brain injury (ABI) result in longer recovery times compared with lower limb. Intensive neurorehabilitation promotes a good long-term functional outcome. Virtual reality (VR) and video game technologies are invaluable adjuncts to traditional neurological rehabilitation as they help to motivate, engage and gain children's compliance in goal-directed therapy. However, this technology is not routinely used in the National Health Service, UK; it requires embedding to benefit children and their families. VR implementation in rehabilitation practice requires development. The associated influencing factors require further exploration before routine use can be established. This project aimed to understand the factors influencing the use of VR in upper limb rehabilitation in children.

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Design An interpretative qualitative study used focus groups and 1:1 semi-structured interviews conducted in person and online to explore participants' experiences. These were analysed for inductive overarching themes, particularly focusing on the views of professionals and young people regarding the use of VR in upper limb rehabilitation.

Setting Two neurorehabilitation services located in two children's hospitals in England, UK.

Participants Three physiotherapists, five occupational therapists, a play worker and four members from the Young Persons' Advisory Group took part. Four focus groups with 2–4 participants in each group and two 1:1 semi-structured interviews were conducted. Thematic analysis was used to create the model participants described as the factors that influenced the use of VR in neurorehabilitation.

Results Five closely related major themes and thirty associated subthemes were developed: training, knowledge, promotion, consideration of barriers and family factors. There is a lack of knowledge and understanding about the use of VR, its limitations, and the clinicians' motivation to use it. Training packages with available VR equipment, clinical indicators and scientific evidence are required. Staff need frequent training, logistics (uninterrupted Wi-Fi, software, hardware) and simple instruction manuals.

Conclusion To introduce VR into the routine rehabilitation of children with ABI, investment in improving knowledge, frequent training and positive behaviour change among health professionals is needed.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study gathered therapists' and young people's views on using virtual reality for rehabilitation.
⇒ Participation was broad and inclusive of therapists and young people's groups.
⇒ A 4i model (improving knowledge, investing in training, infrastructure and implementing changes) is suggested.
⇒ Members checking was not done to improve triangulation.

INTRODUCTION

Worldwide, acquired brain injury (ABI) is one of the most common causes of neuro-disability in children and young people (CYP).[1] In the UK, ABI accounts for 35 000 childhood presentations to emergency departments annually.[2] Of these, 5% have a moderate to severe brain injury.[3] A subsection of children with ABI have a stroke-like presentation and have a functional loss of an upper limb that results in an increased dependency.[4]

Evidence indicates that upper limb function takes longer to recover than lower limb function in the adult stroke population.[5] Neuroplasticity is vital in regaining motor skills following brain injury.[6] Dendritic growth and synaptic changes in the brain are linked to neural plasticity.[7] Repetitive, purposeful and goal-directed movements are required to induce neural plasticity. Following ABI, children often require early and intensive neurorehabilitation to achieve their maximum potential.[8] High-intensity and repetitive practice require a high level of labour-intensive therapy, often difficult to provide due to high work demands and capacity issues.[9] These children can be passive, and parents struggle to motivate them to do the prescribed exercise.[10] Most

children, however, do enjoy playing computer games.[11] Virtual reality (VR)-based computer gaming technology is emerging as a valuable adjunct to traditional neurological rehabilitation.[12] It has been recently used to treat CYP with cerebral palsy (CP)[11] and ABI.[13] VR has been shown to improve upper limb functions in children with CP when used with conventional therapy.[14] Motivation is a crucial element for active participation in neuro-rehabilitation. VR has been shown to improve the upper limb functions of children with CP Manual Ability Classification System levels III and IV.[11]

VR interventions need less professional input and can be programmed to suit an individual child's needs. This type of intervention helps address boredom and adherence to interventions while facilitating increased therapy time and may not rely on therapeutic contact time.[12] Parents are empowered to facilitate the active participation of children. However, VR has not been used routinely in the UK National Health Service (NHS).

A cross-sectional survey in Canada that examined the use of VR by therapists reported that 46% of therapists had VR experience, and 15% of them had used it to treat people who had suffered a brain injury. This study found that lack of funds, space, time, support staff and appropriate clients were barriers to using VR; they found that client motivation, therapists' knowledge and management support were the facilitators to enable VR to be used in regular practice.[15] Farr et al.[12] examined the paediatric physiotherapists' (PTs) and occupational therapists' (OTs)' learning needs of VR in the UK and noted that only 11% of therapists reported current use of VR as a rehabilitation intervention with their patients; managers have little or no influence on VR adaptation, and the lack of IT support is another barrier.[12] Farr et al.[12] recommended that tailored support is required to facilitate VR adaptation.[12]

In rehabilitation, treatment goals have shifted from managing the body structure to managing activity limitations and participation restrictions.[16] Our previous co-production work with children who have neurological motor disorders showed that the children found formal exercise lacking in salience and variety; they found that it was hard to fit their exercise programme into their daily life; it competed with academic needs; it isolated them from their peers; and it was harder to do the programmes as they grew older. They recommended play-based activities, video games, and VR-based activities that fit in with their life and would be more acceptable because they could play with their friends/peers and siblings. In line with these outcomes, therapists must evolve from conventional hands-on therapy to next-generation technology-based therapy programmes that facilitate personalised care.[9] VR can be seamlessly embedded in integrated services to improve patient care and efficiency and promote functional outcomes.[15] For this, VR Intervention requires development, and the associated influencing factors need exploring before it can be used routinely in rehabilitation.

This study aimed to understand the factors influencing VR use in upper limb rehabilitation for children with ABI and to determine the infrastructure support and training required for therapists to plan and deliver personalised VR programmes.

METHODS

Design

A series of qualitative semi-structured interviews was used to explore participants' experiences and analysed for inductive overarching themes using inductive thematic analysis. The focus was on professional and young people's views of VR for upper limb rehabilitation. The authors followed the Standards for Reporting Qualitative Research Checklist[17] (online supplemental appendix 1).

Ethics

This study was registered with the Birmingham Women's and Children's Hospital Research and Development office and in accordance with the UK National Research Ethics Service guidance (REC: 16/BWC/LA/Rathinam).

Patient and public involvement

Patients and the public were not involved as this study aimed to understand the therapists' need to use VR in clinical settings.

Participants

All the physiotherapy and occupational therapy team members of the Birmingham Children's Hospital (BCH) and Oxford Children's Hospital, treating children with ABI were invited. Purposive sampling strategy was used. Three PTs, five OTs from both centres and a play worker (PW) from BCH agreed to take part and gave verbal consent. We also invited BCH's Young Persons' Advisory Group (YPAG); four members (13–16 years) consented through their coordinator. The therapists' and PW's professional experience and use of VR for treatment over the years are given in table 1. Appointments were scheduled to meet the participants in person or through

Table 1 Number of professional and virtual reality use experience among the participants in years

Participant	Profession	Experience (years)	
		Professional	Virtual reality use
1	PT	32	4
2	PT	17	0
3	OT	6	0
4	OT	4	0
5	OT	20	0
6	OT	20	0
7	OT	10	6
8	PW	4	1

OT, occupational therapist; PT, physiotherapist; PW, play worker.

an online platform (Microsoft Teams); the YPAG coordinator was present when meeting the YPAG group.

Procedure

Between two and four participants per group attended four focus groups, and two 1:1 semi-structured in-depth interviews were completed, each session lasting between 60 and 90 min according to staff availability. Participants were offered both options of a 1:1 interview or a focus group, and take-up was according to personal preference. There was no remuneration for participants. A semi-structured interview guide was used to facilitate discussion (online supplemental appendix 2). Participants were asked about their VR experience, barriers, adherence factors and reflections. CR undertook all interviews, and the interviews were recorded with permission. Written notes were taken simultaneously. CR is an experienced clinician working with children with neurodisability, and positionality has been developed through systematic review published[10] in this area. CR maintained reflexivity by diary keeping during the interview and analysing the transcript.

Analysis

Interviews were transcribed in full. All transcripts were deidentified. Pilot coding and training took place between WF and CR. Thematic analysis was conducted following Braun and Clark's (2006) guidelines, and was conducted by hand. A multistage approach included familiarisation, indexing, sorting, developing an initial framework, applying the framework, and charting the data, and interviews were read and coded until the saturation point was achieved. Interpretation followed to analyse the collected data.[18] An initial line-by-line inductive coding was performed verbatim. This enabled themes to evolve from the data related to the project aim. These themes were categorised, and five major themes and associated but interrelated sub-themes were developed. Trustworthiness was ensured by triangulating the data gathered with the previous study data (WF). Analytical rigour was maintained with an audit trail, and the coding between the authors was aligned across independent coding of transcripts and multiple reviews to align emerging themes (CR and WF).

RESULTS

Thirteen participants (three PTs, five OTs, a PW and four participants from YPAG, along with their coordinators) consented and participated. All the professionals were aware of using VR for rehabilitation, but very few had any experience, and most reported no experience using it for treatment purposes. A model describing the factors influencing VR use in neurorehabilitation was created (figure 1), and verbatim quotes demonstrating pertinent quotes for individual themes are presented below.

Knowledge

VR is considered a relatively new domain, and lack of knowledge and awareness are two factors that limit any therapists' use in the clinical setting.

VR tools

Participants were all aware of the use of VR for treatment purposes. Many assumed that VR was an immersive technology using goggles or a headset. They needed to be made aware of the non-immersive style. They were keen to understand the different types currently available for rehabilitation, how they work and how they can be used for rehabilitation.

> "I would need to understand how virtual reality works. Would it be a headpiece? Would it be a kind of feedback thing on a screen?" (Participant-1)

Evidence base

Participants were unaware of the existing evidence supporting the use of VR. If the evidence shows validity, transferability and generalisability, it will enable them to make informed decisions. They asked for specific information about the indications, contraindications, limitations, patient position and the minimal ability required to engage children in a VR session. They asked for details about different VR techniques, timings, progression mechanisms, expected changes or improvements, desired outcomes, treatment effectiveness measurements and other factors supporting VR's clinical utilisation.

> "….knowing the evidence base, and what the validity of it is, and if they have been a particular success in particular patient groups, any limitations on kind of age or cognitive ability or physical ability as to what they can, who can use it, like knowing how to make a good patient selection." (Participant-2)

Decision-making

Choosing any modality for treatment underpins the relationship between clinical reasoning, evidence base and equipment availability. This is also related to knowing a child's condition and the parents' capability. Participants were keen to know how and when VR should be identified as an intervention. This will be a clinical decision by the treating therapist, following a good-quality assessment of the child and identifying the goals of all concerned. Only then can it be determined whether VR equipment will assist in achieving the goals.

> "….a good quality assessment, that means that we've gotten to know that child and their context and their family…." (Participant-3)

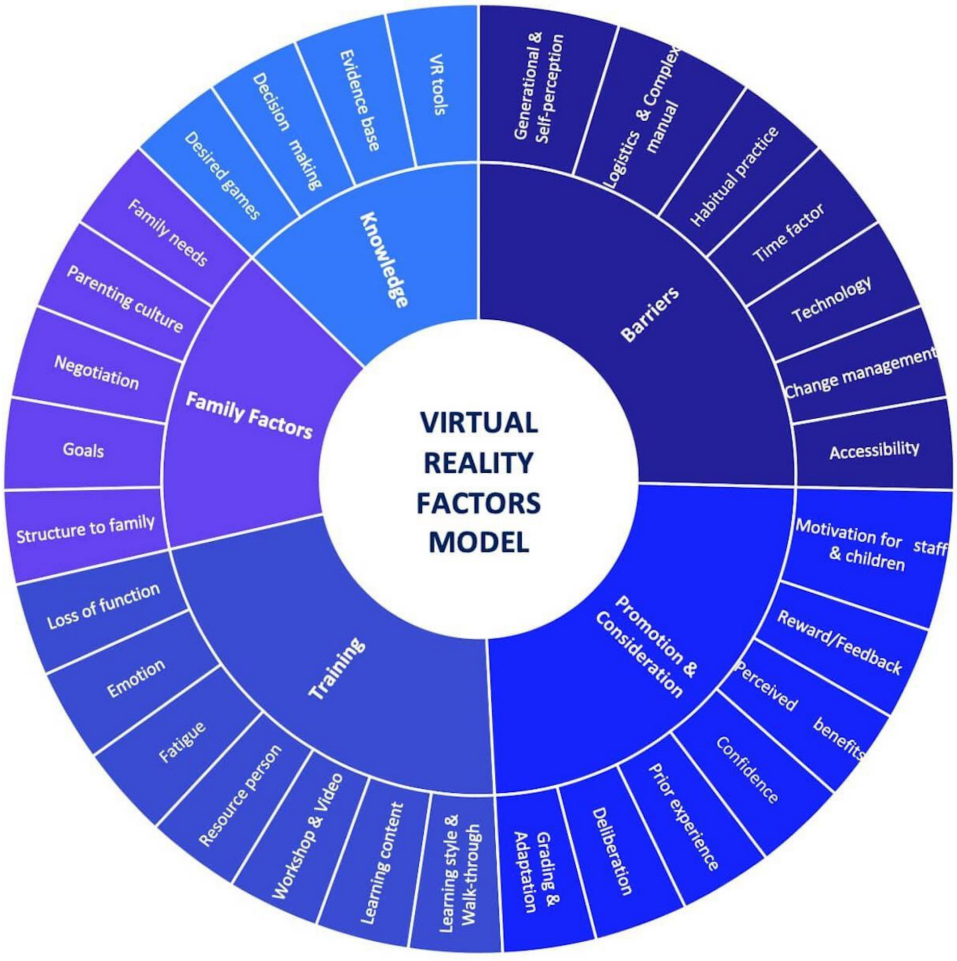

Figure 1 Model of factors influencing virtual reality use for upper limb rehabilitation for children with acquired brain injury.

Desired games

The participants expressed their views on the type of games to choose and which to avoid. The games should give a positive experience, some of which can be achieved through good graphics, up-to-date software and equipment, giving them the feeling that they are playing proper computer games. There need to be various games to avoid boredom, which naturally moves to different levels as the child progresses. They should have the option to change the features so children can easily play without tiring, and a bigger switch control mechanism.

> "….variety of things (games) so that they don't just play one game and then they are bored of playing that one, they have a good variety, and they can play." (Participant-4)

Participants had suggested avoiding games that are gender stereotypical, horror games and car crash games, particularly for car accident victims. Therapists also need to be mindful of not setting up games that can show what the child cannot do to avoid giving them negative feelings, a sense of failure and a risk of disengagement when they find the games too hard.

> "….acquired brain injury (be)cause, let's say it happened in a car crash, then you bring this piece of kit, and you're playing a car game. It's gonna be a bit triggering…." (YPAG-1)

Training

Lack of training has been identified as an essential factor limiting VR use in clinics. Participants highlighted their training needs related to the child's functional loss.

Loss of function

Some children lose their motor function following ABI. This is especially true for those who have a stroke-like presentation or tone abnormalities. These children struggle to use their hands for everyday functional activities, impacting their independence and disrupting their development. At times, they struggle to entertain themselves. Participants were keen to understand the barriers to using VR during the acute phase. These include having a cannula in their hand, frequent seizure episodes and not having part of their skull following brain surgery.

> "….if they have lost the use of their hands, they really struggle with…." (Participant-8)

Emotion

Emotional regulation is often challenging, and these children often get frustrated when they have lost independence or skills following ABI. Although they know what happened to them, they often do not reflect on why. The psychological impact includes feeling low and scared, and they wish to go home instead of being in the hospital. They become aware of what they can play despite cognitive and learning problems but are depressed as they cannot manipulate small controls in their VR consoles.

> "….They've just got a brain injury. They feel grotty. They're scared. They don't want to be in hospital, but they don't really quite know what they want…." (Participant-5)

Fatigue

Fatigue is a common problem experienced by children with ABI from the early stage, and most of them tend to have this problem on a long-term basis. The participants want to learn the early signs of fatigue or tiredness, so stop the session at an appropriate time or help parents recognise fatigue and differentiate between tiredness and boredom. This will also help negate fatigue by pacing, changing the game's complexity and modifying the VR's intensity.

> "most of the time, they have got tired….and I've had to stop." (Participant-8)

Resource person

Participants have suggested a resource person within their team to keep their skills, be responsible for ongoing training, and demonstrate that VR works. The resource person can also take responsibility for reviewing the VR programmes regularly and ensure that the family is competent in delivering it while in the ward. The participants commented that they need time to practice VR and a higher training volume to maintain competency so that it can become second nature. They wanted yearly and frequent refresher training programmes to ensure learning reinforcement.

> "We would want to always ensure that we've demonstrated and that the person is using it in the correct way…." (Participant-3)

Guidance Workshops and Video

Participants suggested frequent workshops for therapists, parents and children, along with pre-course materials about VR systems and how they work to educate people. The workshop method was considered helpful as it offers practical opportunities to work with the VR sets, reinforces learning by repetition and provides ongoing support. Journal club, keeping abreast of the research and constant refresher will minimise difficulties in using VR.

> "….having a field training module where people could see this sort of troubleshooting guide. So the basics of how to connect to the Internet, Bluetooth, troubleshooting…." (YPAG-2)

YPAG participants suggested a YouTube channel containing training videos for parents, children and clinicians for VR training. Video content includes tutorials such as instructions on setting up the VR, how to play, troubleshooting and frequently asked questions and answers.

> "….could have like a YouTube channel and it's basically like to the people (who) have already used it, find out their most common problems and then you can specifically have a video that (shows) how to fix this." (YPAG-1)

Learning content

As part of the training, the participants suggested that the learning content should contain VR's benefits, clinical utility, indications and suitability for different age ranges, settings, and game variety and complexity levels. Additional information, such as how VR can be used in a therapeutic way to treat other problems, collecting, analysing, and interpreting data to see what the patient has done, and how VR aligns with other treatments, were also required. The learning content is expected to include further details about ease of use, difficulties, pros and cons, and treatment dosage for optimal outcomes. If specific VR equipment has been used, the participants were interested in learning the manufacturer's data, equipment information and repetition altering mechanism to avoid fatigue, charging and readjusting the units. From the patient's perspective, the participants needed further training in goal setting, how VR fits within their rehabilitation programme, and the functional activities and muscle groups they were exercising. This information was considered beneficial to training families to use VR under the guidance of therapists.

Learning style and walk-throughs

The participants expressed different learning styles and strategies. Although a training manual is available, it does not allow the learner to ask questions, and they prefer learning on the job and training in person. Some expressed the need to learn personally and to use VR frequently, which would help to reinforce their learning and increase their confidence. Demonstrations and sitting with experienced users were the preferred methods because it would allow them to ask questions and practice under supervision. Participants wanted much handholding, slow explanations of the functions, and to be walked through the game, especially when they began using it.

> "I would like just some guidance on what to do with them and how far to push them, and that would be great for my training needs…." (Participant-8)

Barriers

Habitual practice

Therapists are accustomed to working with minimal resources. Therefore, technology is not usually considered a treatment option despite its availability. For example, some of the therapists still draw their exercise programmes instead of using computer-generated programmes. Any new treatment technique requires time for evaluation and reflection. If the technology is not working, they prefer to return to old treatment techniques as they need more time to investigate and troubleshoot. This means that the new technology is not used frequently, which leads to a lack of familiarity and a decreased inclination to use it without further training.

> "….I am still drawing stickman for the exercise programme because trying to get to the computer to log on to (write an exercise programme is) hard to navigate and crashes all the time. When you know your patient is improving so quickly and you will need to redo this exercise programme in two days, it actually just stops me using it all together…." (Participant-2)

Generational and self-perceptions

Some commented that they were old-generation therapists and too old to try VR. They felt that the generational difference between therapists and children is vast, and there is a gap in knowing what the children like and how to play with them using VR. They lacked the experience and confidence to use it for therapy purposes. Some therapists and YPAG participants who had tried a VR headset reported feeling sick and disliked using it. Those who had tried VR reported that they were not technology literate, felt rubbish and needed to remember about using them.

> "….I'm not a gamer; gaming (has) been around for a long time, but I'm not one. But actually, the immersion in technology and the development of the internet and everything has really only been in my adult life." (Participant-1)

Logistics and complex manual

The participants reported many logistical issues. For example, communication between part-time staff, such as sharing information and hand-over, is problematic from a staffing perspective. Having a designated safe space is a challenge, as therapists often need guidance on where to treat these children or where to store the VR equipment. Connecting the VR units to the internet is a challenge, and the participants felt that having easy access to IT services may overcome this issue. Although manuals are available, participants reported that these are complex, and hard to navigate and find the solution. Therapists wanted a simple laminated crib sheet or a quick starter guide explaining troubleshooting, screenshots of what has been shown in the manual, set-up, games and calibration techniques.

> "….the problem with the manuals and things are so long often that you can't find the thing that you're looking for…… having some crib sheet that quickly tells you this would help with this aspect…. (Participant-5)

From the equipment perspective, some need to be reset each time the children play a different game. Some children find it hard to grip the VR sets and need to readjust their handhold for each new game. For the complex VR sets, the children need someone around them to set up the programme, motivate them and engage in the games for therapy. This is a challenge after their allocated time with the therapists, particularly over the weekend. This usually results in children not doing anything over the weekend. Most VR gadgets are made for typically developing children, and very little equipment is available for children with disabilities. When children with ABI tried to use the usual consoles, they found it challenging to manipulate them and they tired quickly. Most children had prior experience of playing VR games with rich visual content, but rehabilitation-focused games are generally primitive; hence, children quickly lose interest.

> "….kids these days will have high expectations from the point of view of graphics and action quality because of what they see in films and games." (Participant-2)

Time factor

Lack of time is a common problem expressed by most of the therapists. They acknowledged that they need dedicated time for training to use VR properly. Despite the availability of the systems, therapists need more training time and clinical time to use them appropriately.

> "….but often we have to reset it 3, 4, 5 times to make sure that (all) the Wi-Fi connectors are actually connected. So, for one successful session, it's about 2 hours. So that means 100% more time than you (usually spend)…." (Participant-5)

Technology

Many participants reported that poor Wi-Fi connectivity in their hospital limited their opportunity to use VR. They commented that the connection would not work or the equipment would not pick up the signal. Having a reliable network connectivity is vital if VR is to be used in the hospital setting.

> "I think the practical difficulties in the hospital is lack of time, space, Wi-Fi, general resources (which) make it very difficult to be consistent in anything that needs a set-up" (Participant-4)

Participants believed that the technology constraints listed above often put them off. It requires a lot more support if it is to be used effectively, which defeats the purpose of why VR was introduced in the first instance.

"….if the IT set up for this sort of thing was not easy to use and not reliable, that would make me use other adjuncts instead…. I'll spend an hour setting it up and then it won't work anyway" (Participant-2)

Change management

Participants acknowledged that people take the path of least resistance and that they generally do not like change. They require convincing and demonstrating the utility, as people are not tech-savvy. They suggested example videos of VR in practice, showing how children used it and the outcome achieved.

"….it's a change in practice, so people don't like change. Particularly and will only engage if the change is managed, almost like a change management way….it's about saying, 'this could help; why don't you give a (try)'." (Participant-1)

Accessibility

Lack of space is an essential factor that limits the use of VR. Leaving the system close to the bedside in some wards takes a lot of work. In some places, expensive units are available, but therapists have yet to be trained to use them. Sometimes, more minor issues, such as missing cables or sets needing to be charged more, caused embarrassment when the session was disrupted. Many therapists felt excited initially to use VR but became reluctant because of accessibility issues; therefore, sustaining enthusiasm is difficult.

"….it's also about how we've gotta make it accessible to everybody. In our department, we find all the expensive kits that once were the pride and joy and are now stuck at the back of a cupboard because nobody can remember how to set up the Wii or nobody's got the key to get the search insert. So we've got all these pieces of kit, but I've never seen them used." (Participant-6)

Promotion and consideration

Motivation for staff and children

The YPAG suggested different strategies to promote VR for rehabilitation purposes. These included age-appropriate games, offering taster sessions, encouraging games with parents or siblings, challenging others or beating their previous scores. Watching other children enjoy VR may enthuse disinterested children. Promoting VR success stories online, getting people to talk about their experience, having competitions by playing against each other with a leader board, and playing interactively can give reassurance and motivation.

"….you should get other kids to try it out in front of kids that don't wanna do it yet…." (YPAG-3)

Reward/feedback

From the therapists' perspective, VR is not a universal treatment provision but an additional tool that can be used in conjunction with their usual treatment. Positive feedback is always a good motivational factor. This feedback can be the visual displays on the game, a certificate for reaching certain milestones, or purely verbal feedback.

"I definitely like that when they get the feedback as well, like party, pop sound effects or something just to kind of go well, you know, it's that big 'Well done! You've just done that level'." (Participant-5)

Perceived benefits

All the participants acknowledged that children love computer games and VR. They can spend hours playing as it is enjoyable, fun, engaging and interactive. Therapists felt that VR helps to improve the child's engagement, which can facilitate movements, increase movement control, and facilitate stability and function. The end products are improved performance, grip strength, muscle length, satisfaction, spasticity management and function improvement underpinned by component skill development. VR helps to distract the children, get them moving and enable them to do their therapy without realising that they are doing it.

"Children love gaming, so I think it's a great way to distract them and actually get them a bit more moving." (YPAG-3)

VR can also be used for motivation instead of therapy, especially for fun if they do not want to do anything in the ward. VR also has the potential to make hospitals more interesting, turning a 'no' person into a 'yes' person by trusting their therapists. It empowers parents to improve their independence.

"He was smiling and laughing, and that was the first time I'd seen that…. you're not going to do anything horrible and that just playing computer games and that did have a knock-on effect as well to his positivity in other sessions." (Participant-5)

Confidence of healthcare professionals

Participants who had prior experience using VR were confident in turning on Bluetooth, adjusting tables to use VR, deciding suitable VR games for different age groups, selecting games' complexity, progressing to the next level if the child achieved the target, using different movements and techniques to control VR and helped them to use both hands. However, confidence varied:

"Do people feel trained & confident & competent?" (Participant-1)

"We don't have confidence…." (Participant-6)

"I'd like you to guide how to do it…." (Participant-8)

Prior experience

Some therapists had experience in using VR and noted that it was beneficial. It was used to improve attention and concentration, engagement, movements and strength. They learnt that a child does not need much movement to operate VR to use it at a low level. However, the lack of Bluetooth connectivity limited the VR unit's use for treatment and led to frustration. Children lost interest quickly when the system did not work, and it compromised other aspects of therapy. Apart from connectivity, they have noted other challenges, including children being competitive and making it too difficult for themselves. Therapists had assumed that parents understood the treatment goals and could follow what they were seeing, but this was only sometimes the case.

> "I've had that a few times, and then they lose interest really quickly, then they lose their faith in you knowing what you're doing because the whole system is just not working. So, if you're not careful, that can rub off on other aspects of your therapy, and you don't want that." (Participant-4)

Deliberation

Participants from the YPAG group suggested that the commercially available VR games they are playing are fast-moving, high-motion simulation, and have loud sound effects. These games will be challenging to play for children with ABI due to their slow reactions; the effects of flash and sound effects on eyes and ears, especially when most already suffer from headaches. Therapists deliberated about whether they could advocate screen time for the acute ABI children, when it would be appropriate to engage them in VR, and what games and equipment would kindle a child's interest and maintain their motivation to exercise and facilitate them taking responsibility. They would want to ensure that the child and their family perceived it as therapeutic and that barriers to its use for rehabilitation were minimised.

> "….it's not good for an injured and healing brain to have a lot of screen time because of the way it fires up all your neurons…." (Participant-1)

Grading and adaptation

Children with ABI experience various complex challenges, including slow reaction speed; therefore, adapting VR games is vital to make it inclusive for everyone. Adaptation of VR requires consideration of a child's age range, physical and cognitive ability, concentration and engagement, communication issues, sensory impairment, and hearing and visual impairment. In the acute phase, the children struggle to be in a busy ward environment where the noise and other distractions limit their focus in therapy sessions. These children will require both the games and their environment to be adapted. Instructions should be clear and concise for all parents to understand.

> "In terms of understanding families and making sure that they can understand the instructions…. you need to adapt how you gave the instructions or how the interface worked…." (Participant-1)

Family factors

Family needs

Digital illiteracy and digital poverty are essential factors, as some families and parents may need access to technology. During the acute rehabilitation phase, families struggle to cope with sudden changes, and it was considered hard to expect them to engage their children in VR programmes.

> "….thinking about high incidences of and younger parents, high incidences of parents who might not have access to technology, high incidences of parents who might have needs, learning disability, physical disabilities themselves. How are we expecting them to carry over…." (Participant-7)

Parenting culture and negotiation

Parenting covers a massive spectrum that is influenced by cultural and historical context; any technology intervention should fit meaningfully around the family culture and belief system. Having cultural sensitivity around parenting and boundaries is required. One aspect of this that therapists observed was the varying approaches to technology access and screen time. Parents must see the value and feel confident that VR will support their child's rehabilitation. Therapists suggested negotiating a set-up programme with the parents.

> "….different parents might have different parenting approaches relating to access to technology and screen time, and one of the jobs we'd have to do to set up a treatment program is negotiate that with them." (Participant-6)

Goals

Engaging family and children around personalised goal setting is considered paramount. The therapist's role is to decide whether VR helps achieve the agreed goals.

> "….we don't want to set people up with a device that measures their failure because that's really disheartening." (Participant-3)

Structure to family

Families need to use VR for the well-being of their children, and they require a structure around the use of VR. This includes clarity about how VR will be used, a timetable for VR games, and limiting the play time and frequency when playing complex games. Participants initially recommended playing for 10 min and building up if the children were eager to play further. They have suggested playing between 5 and 45 min, morning and evening, and having a break between sessions.

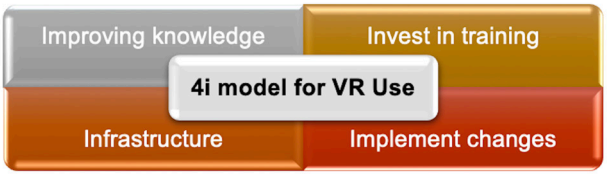

Figure 2 4i model to use implement VR for upper limb rehabilitation. VR, virtual reality.

DISCUSSION

This scoping work is based on the perceptions of therapists, clinicians, YPAG members and people in an NHS setting when using VR for rehabilitation. Five major themes relating to issues around knowledge, training and implementation emerged. Four key principles ('4i') were developed, which need consideration by professionals when using VR in upper limb rehabilitation (figure 2). Those four principles structure the discussion.

Improving knowledge

Evidence-based intervention is the current principle that enables clinicians to use interventions with confidence.[19] To facilitate VR intervention, the NHS workforce requires extensive investment to improve awareness, knowledge and convincing evidence base in VR use. Although VR technology has been used for rehabilitation for over two decades, there are not enough high-quality studies encouraging clinicians to use VR in routine practice.[12] Commercially available VR equipment has not been used by the ABI population and requires adaptation of VR equipment. It may not be possible to conduct research to the level of randomised controlled trials, especially under individual conditions; therefore, translating the knowledge gained from other conditions, such as adult stroke and children with CP should be considered within the paediatric ABI population.

Invest in training

Therapists have trained to be 'hands-on' and require considerable and extensive training to adapt technology for treatment. Therapists often feel uncomfortable trying new technology as part of their practice due to their age perceptions.[15] Introducing new technology requires considerable training to change behaviour.[11] Various learning and training models and descriptors of available VR equipment, clinical indicators and participants' experience need consideration when designing training packages. VR needs to be embedded in routine practice to facilitate behaviour change. Tact *et al*.[20] have suggested a digital adaptation framework for the NHS workforce, and it can be considered for technology-related training and education. Technology-based intervention must be a core skill gained through graduate training so future therapists can become early adopters.[21 22]

Infrastructure

Basic infrastructure provision will eliminate many barriers to using VR for rehabilitation.[23] Early adopters or technophobes within the workforce are at risk of abandoning VR if the required resources, such as uninterrupted Wi-Fi, updated software and user-friendly hardware, are not readily available. Participants perceived that much of the available rehabilitation-focused VR equipment was heavy, came in universal/uniform sizes only, was hard to operate, unstable and time-consuming. Finally, attrition of technology limits its use due to poor longevity, and a lot of equipment needs upgrading in healthcare settings due to ongoing cost factors associated with degradation over time.[24] Technology readiness is one of the main issues organisations face; the poor compatibility between the evolving technology and the existing electronic health records often limits this.[25] The evolving evidence base, lack of user guidelines[26] and uncertainty around personalised applications,[27] alongside accessibility and cost factors, further limit the organisation's ability, willingness and capability to use technology.[28] The introduction of digital technology, including VR, should take place alongside investment in the stability of the approach to rehabilitation, including the required infrastructure should be in place.

Implementing change

Our findings suggest that human factors play an essential role in digital adaptation. Various factors related to affordability, digital poverty and the family's readiness to try technology as a tool significantly limit the uptake of VR for rehabilitation. The NHS has a digital technology framework for allied health professionals[29] and a long-term plan for digitally enabled care.[30] However, the embodied reality is far behind and in relative infancy. If NHS organisations commit to embedding digital interventions as a high priority, and investing heavily in their workforce and resources, technology-based interventions such as VR will likely reach end users. Therapists are also responsible for changing their rehabilitation strategies by moving away from traditional models and adopting positive approaches of early adopters, which will lead to the evolution of future leaders who will crystallise further embedding of change. For example, a group of practitioners have used VR for ABI rehabilitation and noted the improvement and engagement of children. A recent survey indicates therapists' higher confidence and motivation when using digital technology.[20] This indicates either a step change in therapists' age or a sea change in the UK's commitment to health services. Either way, it is a positive sign.

Our findings enable us to understand factors that need addressing in the implementation of VR for ABI rehabilitation. Implementation is a complex process that requires managing barriers at various levels with multiple and holistic strategies. Kouijzer et al.[31] suggested using an implementation framework that facilitates behavioural changes of all the stakeholders to integrate VR into healthcare practice.[31] VR intervention can be developed by addressing the issues identified in this work, and a future feasibility study is needed to see if VR can be used for upper limb rehabilitation in children

with ABI, additionally focusing on the implementation issues from the beginning.

Limitations

This study did not report the parents' views of using VR, and this could add value to the themes developed. Triangulation of views was limited due to time availability of the clinicians, which could be strengthened with expert review, such as Delphi approaches but was not possible. A larger study would have encompassed more participants and a number of clinical service centres. Only two therapists and a PW who took part in this project had some experience of VR, and the remaining therapists' views appear to be their perceptions rather than their experience of using VR. As a result, generalisability is not possible, but re-occurring themes could be made with some surety due to analytical saturation.

CONCLUSIONS

The use of VR technology for upper limb rehabilitation of children with ABI depends on investing in training for health professionals to improve their knowledge and thereby implement changes in rehabilitation techniques. We must invest in improving knowledge, repeated training and positive behaviour change among health professionals to use VR technology for upper limb rehabilitation of children with ABI.

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