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Virtual reality based executive function training in schools: The experience of primary school-aged children, teachers and training teaching assistants

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ABSTRACT

Executive function (EF) is a set of higher order cognitive processes through which learning and everyday goals are realised. They comprise the fundamental building blocks of how we plan, execute, monitor and regulate tasks, and impact our cognitive, socioemotional and behavioural responses. An important question to consider is how we can support children to develop effective EF skills through motivating and age-appropriate training. Virtual reality (VR) offers an interesting avenue to enhance motivation due to the experience of presence and immersion, however, whether children experience presence and immersion similarly to adults is unknown and could impact the educational utility of VR over other media. In order to understand whether VR is suitable for an educational setting we must understand the experience of key stakeholders, such as school-aged children and adults that will be facilitating use in the educational context. Therefore, the current study aims to understand the experience of key stakeholders using EF training delivered in a VR environment, to enable reflection on the feasibility and usability of the technology. This study aimed to explore the qualitative experiences of 8 primary school-aged children, 5 teachers and 13 training teaching assistants, after playing an EF training game, Koji's Quest, on a VR head mounted display. Firstly we found that most teachers and trainee teachers gave good ratings of usability, but in their subjective descriptions of use focused on hedonic experiences, whereas, children focused on pragmatic experiences. Results also indicate that adults may favour 'being' definitions of presence, whereas child participants appear to incorporate both 'being' and 'doing' definitions into their accounts. This research has implications for how VR based EF training can be maximised within an educational setting.

1. Introduction

In their review of motivational theory, Eccles & Wigfield (2002) state that "it is difficult if not impossible to understand students' motivation without understanding the contexts they are experiencing" (2002, pg. 128). This is the primary concern of this research: To unravel the subjective experiences of virtual reality (VR) users to understand what motivates or demotivates them within the context of executive function (EF) training. For children, this means knowing what will motivate them to persevere. For adults, this means knowing what will motivate them to invest time and resources into learning a new skill that can be utilised in the classroom.

EF is a set of higher order cognitive processes through which learning and everyday goals are realised. They comprise the fundamental building blocks of how we plan, execute, monitor and regulate tasks, and impact our cognitive, socioemotional and behavioural responses. There is broad agreement in the importance of EF to a wide range of outcomes, and researchers agree that where deficits in EF are identified, individuals are at risk in several ways, including school readiness and academic achievement (Diamond & Ling, 2019) and reading and maths skills (Farhi et al., 2024; Strobach & Karbach, 2021, p. 335). EF training has been shown to be successful in a range of areas including reading (Johann & Karbach, 2020; Titz & Karbach, 2014) and there is also evidence that EF training might be more efficacious with specific groups, including attention deficit hyperactivity disorder (ADHD) (Singh et al., 2022) and autism spectrum disorder (ASD) (Zhao et al., 2021). Effective EF training, therefore, has the capacity to change lives. Significant research in the area of EF training has often utilised computerised training (Johann & Karbach, 2020; Plass et al., 2019; Wang et al., 2019). Advances in technology however, mean that attention has now turned to the possibility of delivering EF training using VR.

There is growing evidence to suggest that VR can be used to support academic outcomes. For example, the work of Makransky et al. (2019) considered behavioural outcomes between students from three groups.

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Participants were allocated to one of three mediums (immersive VR, desktop VR and a conventional safety manual) for delivering laboratory safety training. After the training, participants in the immersive VR condition performed significantly better than those given the conventional safety manual in terms of solving problems in a physical laboratory setting. This would suggest that one of the benefits of this technology is the ability for students to *enact* a specific skill. However, it is also essential to consider the potential impact on cognition, as this experience of VR is arguably distinct from other modes of educational delivery. There is evidence to suggest that for some tasks, the use of VR may be disadvantageous. For example, the work of Parong and Mayer (2020) compared the use of VR to a desktop slideshow. Participants in the VR group performed significantly worse on the transfer tests, reported higher emotional arousal and reported more extraneous cognitive load. They conclude that there may be a higher affective and cognitive load in VR, which leads to poorer outcomes.

Exploring and understanding the impact of VR on EF training requires two layers of influence to be examined. Firstly, it is plausible that the subjective experiences of the target user may have an effect on the cognitive processes involved during completion of the training tasks. For example, a positive and rewarding experience may increase users' motivation to play the game, or to persevere when the game is challenging (Jiang & Fryer, 2024). Equally, it is possible that experiences may have a negative effect on cognitive outcomes, through increased cognitive load (e.g., Huang et al., 2020). Secondly, it is essential to position the learner within the unique demands of the educational context. As gatekeepers of time and resources, the technological experiences and attitudes of educational staff are likely to influence access to technology, and the nature of those learning experiences (e.g., Liu & Szabo, 2009).

Although prior evidence demonstrates sufficiently the efficacy of EF training (Johann & Karbach, 2021), and the potential of VR as a learning medium (Makransky et al., 2019), what is missing from the literature is an understanding of how these two areas connect. What is not yet known, is whether VR is a suitable medium for delivering EF training. The primary aim of this research therefore is to understand the impact of VR on both children's and adults' experiences of EF training. This includes a consideration of how VR may impact EF training both during and after the training. Specifically, participants' experiences of motivation, usability and presence will further our understanding of using VR EF training in an educational context and provide insight into whether, and how training can be sustained over a period of time.

1.1. The role of motivation

One of the key reasons for attempting to unravel the subjective experiences of technology users is to understand what it is that motivates or demotivates them. For children, it is useful to know what will motivate them to persevere with an activity; for adults, what will motivate them to invest time and resources into learning a new skill that can be utilised in the classroom. Self-determination theory (SDT; Ryan & Deci, 2000) has been extensively considered in the context of schools (e.g., Núñez & León, 2019; Sergis et al., 2018; Stolk et al., 2018) It has also been specifically used to consider responses to technology, for example, to investigate technology acceptance (Lee et al., 2015), to explain teachers' motivation to continue using e-learning (Sørebø et al., 2009), and to consider digital literacy (Chiu et al., 2022). SDT (Ryan & Deci, 2000) focuses on the elements of autonomy, competence and relatedness, and suggests that individuals will experience higher levels of motivation (and therefore, a higher propensity to continue with the technology) when these three needs are being met. Within the context of this study, these needs can be defined as control of the virtual environment, effectiveness in dealing with the virtual environment, and how the virtual environment supports meaningful relationships with others (Fig. 1).

Research on the educational use of VR has frequently focused on motivation. For example, the work of Makransky et al. (2019) considered knowledge retention, intrinsic motivation and self-efficacy outcomes between students from three groups. Participants were allocated to one of three mediums for delivering laboratory safety training. Although there were no differences in knowledge retention, there were significant differences in terms of intrinsic motivation. This suggests that although the VR medium showed no advantage in terms of delivering the content, the medium was more motivating for the students. In addition, Asad et al. (2021) in their systematic review, suggest that VR is effective in providing experiential learning in a range of contexts; Garduño et al. (2021) and Huang et al. (2021)find VR as a medium to be more engaging; and Tian et al. (2021) suggest that VR may elicit greater emotional arousal. Arguably, this suggests that not only is VR comparable to other media, it may actually be preferential.

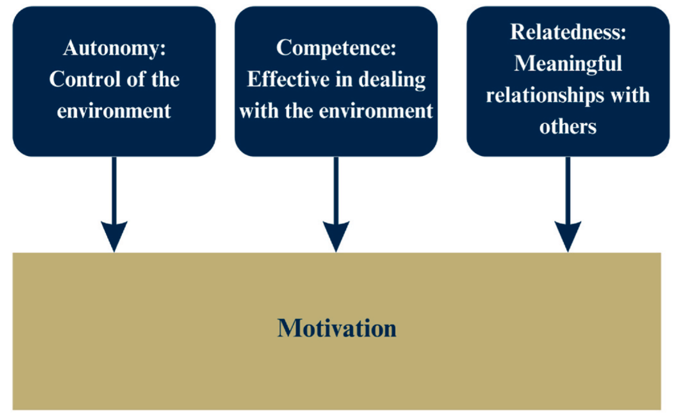

Fig. 1. *Autonomy, competence and relatedness needs, as expressed by self-determination theory* (Ryan & Deci, 2000).

However, the relationship between learning, and motivation is arguably complex and there is evidence to suggest that increased motivation in itself does not lead to increased learning outcomes. For example, Parong and Mayer (2018) compared the instructional effectiveness of VR with a desktop slideshow. Participants in the VR condition scored more poorly on knowledge retention, and higher in terms of motivation. The Cognitive Affective Model of Immersive Learning (CAMIL) (Makransky & Petersen, 2021), provides a useful framework for considering the appropriateness of VR to deliver cognitive training. Their work is built on the assumption of the interaction between method and media. Within this framework, there would need to be compatibility between the method (training of EF) and the media (VR). Their model provides six factors which can be impacted by presence and agency: interest, motivation, self-efficacy, embodiment, cognitive load, and self-regulation. Differences in perceptions of presence and agency may have implications for the individual in terms of motivation and self-efficacy, and therefore for the appropriateness of using VR.

1.2. Usability and experience

In considering a shift from conventional (e.g., computer) to VR media, the usability and experience of the platform is of the upmost importance. In its most basic form, the term usability refers to quality of use, and is focused primarily on how a user is able to complete a specific task or goal (McNamara & Kirakowski, 2005). More recently, quality of experience has also been tentatively included, which includes subjective areas such as emotional evaluation. This divergence of definition has significant implications for what kind of research questions can be asked, and the most suitable methods for seeking the answers. In her analysis, McNamara suggests that the three aspects of functionality, usability and experience are separate, and need to be considered simultaneously. However, she heeds caution in how these areas are explored, suggesting that each is methodologically distinct, and urging that experience should not be "reduced methodologically to usability" (McNamara & Kirakowski, 2005, p. 203).

Hassenzahl's model of user experience (2007) divides the experiences of users into pragmatic and hedonic experiences. The pragmatic and hedonic experiences are characterised as separate, meaning that users typically perceive these experiences as being independent of each other. For example, an individual may like a mobile phone because it allows them to call their family. Their pragmatic experience is based on the ability to make calls. However, speaking to their family is a hedonic experience; they are able to *be* connected. These feelings are far more associated with the values of the individual, and hence their identity. The pragmatic experience is concerned with functionality; it enables the user to *do* things. The hedonic experience is different; it enables the user to *be* something. The hedonic experience is considered to be a higher-order experience, and also the one that is most closely linked to the user's self-concept. Therefore, it is typically considered that lower-order pragmatic goals are drawn from the higher-order hedonic goals. In short, the individual starts with 'be-goals' and from these derives 'do-goals'. Therefore, this research will consider the experience of children and adults using VR and will accordingly consider the technology in terms of what it enables users to do, and be.

1.3. Understanding 'presence': being or doing?

The unique affordances of VR, specifically presence and agency, potentially provide a qualitatively different learning experience (Makransky & Petersen, 2021). Presence can be understood as an authentic sense of being in a different place (Skarbez et al., 2017); of being transported somewhere else. Agency can be understood as the sense of ownership an individual feels over their actions (Skarbez et al., 2017). It is possible that the features of presence and agency could augment the training experience. The sense of presence may provide a separate training ground away from everyday school activities as well as a novel and interesting experience. The sense of agency may develop confidence and self-esteem and foster a sense of independence.

The concept of presence is essential to an understanding of the effectiveness of any experience delivered using VR technology, and especially so when implementing cognitive training. It is arguable that the sense of presence experienced when using VR has potential to change the experience in fundamental ways; such as creating experiences which are more memorable or more motivating (Jiang & Fryer, 2024). Despite this, defining the concept of presence within a VR setting is far from straight forward, and researchers differ in their focus on this phenomenon. Often, definitions of presence coalesce around the idea of personal experience, for example "feeling like you exist within … a virtual world" (Heeter, 1992, p. 3). In this sense, presence is the outcome of being in, or being transported to, another place. In contrast to this, however, there are definitions which focus on *activity*. Zahorik and Jenison (1998)and Flach and Holden (1998) for example, suggest that "reality is grounded in action".

In their analysis of the language of presence, Skarbez et al. (2017) argue that *being there* definitions of presence can be split into active and passive types. The active type includes a consideration of the ability to act, whereas the passive type does not. It could be argued that definitions which focus on transportation support a passive view of the learner. Environment is everything. In contrast, definitions which focus on activity place the learner in a state of active exchange. Presence is more easily realised by doing, rather than being. This split in definitions is slight but significant: It replicates Hassenzahl's model of usability, and has some important implications for how presence can be measured.

When considering the experience of children within the VR environment it is essential to also consider their stage of cognitive development. There is some emerging evidence to suggest a relationship between cognitive development and subjective sense of presence in VR experiences for adolescents. Hite et al. (2019) have suggested that because younger children are still developing concrete operational thinking, they have not yet developed a more abstract understanding of the world around. In short, individuals capable of more abstract thinking, reported higher levels of control, and lower levels of distraction. Huang et al.'s (2020) study is less conclusive, but also points to the relationship between subjective presence and cognitive outcomes. In their view, they conclude that learning style may influence sense of presence and perceived cognitive load. This underlines the importance of agency within the learning experience, but also has implications in terms of cognitive load. It may be reasonable to conclude that those students who had lower perceived control in the immersive environment, would expend more cognitive effort in navigating the environment, and would therefore have fewer cognitive resources for learning. It would also be reasonable to question whether different definitions of presence may be more suitable for children.

It is clear that within the VR context, the concepts of usability, motivation and presence are inter-related. This is highlighted by the similarities between Hassenzahl's (2007) usability model of pragmatic and hedonic experiences, and Skarbez's (2017) definitions of active and passive presence and is further evident in Makransky's (2021) discussions regarding the impact of presence on motivation. Given that presence, motivation and usability are key to understanding whether the VR media provide a more effective delivery platform for EF training, research is required to reflect on these components in parallel. This holistic reflection on user experience can support understanding of the unique contribution of this media within the educational context.

Therefore, although prior evidence sufficiently demonstrates the importance of EF training in an educational context, and the promise of VR to enhance motivation and engagement, what is missing from the literature is an understanding of children's experiences and the perceptions of educational staff in terms of usability. The primary aim of this research therefore is to understand the impact of VR on both children's and educational staff's experiences of EF training. This includes a consideration of how VR may impact EF training both during and after the training. Specifically, participants' experiences will elucidate understanding of the training experience. In addition to this, a more nuanced understanding of motivation, usability and presence will further our understanding of using VR EF training in an educational context and provide insight into whether, and how training can be sustained over a period of time.

2. Method

2.1. Participants

Participants from three distinct groups were recruited: children and teachers from a Chichester Primary school and University students training to work in schools. All participants were resident in the UK, and were either attending a Primary school, working in a Primary school or training to work in a Primary school. All participants gave informed consent.

Child participants were recruited with support of the school to disseminate information about the project. Eight participants were recruited (F/M = 5/3, M age = 10 years 6 months, SD = 14.87). Three participants had no previous VR experience, four had occasional VR experience, and one had regular VR experience. Five staff from a Chichester Primary school and thirteen University students were recruited. All participants were either in employment in a Primary school, or training to work in a Primary school. Inclusion and exclusion criteria are detailed in Supplementary Material, Table S1. This sample was chosen because it represented a range of information-rich educational perspectives; those receiving education as well as those delivering, or training to deliver education (Staller, 2021).

2.2. Materials

2.2.1. Virtual reality HMD

Pico Neo 3 Pro were used to deliver the VR experience. This included a head mounted display and two handheld controllers which enabled the user to interact and control the experience, and which also provided haptic feedback. The Pico Neo 3 Pro has a refresh rate of 72/90z, and a 98° field of view. Pico Neo has been successfully employed in prior research, including that with children (e.g., Luo et al., 2023).

2.2.2. Koji's Quest

Koji's Quest is a cognitive training game created by Neuroreality. In the game, the player crash lands on a mysterious planet, where they are able to explore various worlds. The majority of participants experienced two of the six worlds. Each world is based on different neuropsychological paradigms, for example, the Wisconsin Card Sorting Test and Go/No Go tasks (further game details are provided in Supplementary Material, Table S2). Prior evidence suggests that gamification is a significant factor in providing EF training Junttila et al. (2022). Koji's Quest has previously been found to be effective in training cognitive skills with children in clinical populations (van de Wouw et al., 2024).

2.2.3. System Usability Scale

In order to establish adults' views about the usability of VR within an educational context, the System Usability Scale (SUS) was used to collect anonymous responses. The SUS was chosen as it is a robust, versatile measure and quick to administer (e.g., Click here to enter text.Bangor et al. (2008) and Lewis (2018)). The SUS contains both positively worded (e.g., I think that I would like to use this system frequently), and negatively worded (e.g., I found the system unnecessarily complex) items. Participants rated each statement on a 5-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). Negatively worded items were reverse scored. Higher total scores indicated greater usability.

2.3. Procedure

2.3.1. Child participants

In order to understand children's experiences of VR EF training, a retrospective think aloud protocol was chosen. The think aloud protocol was chosen as it has high face validity and is highly appropriate for use with young participants (e.g., Schellings et al., 2006). The retrospective version was chosen due to the dangers of reactivity during concurrent think aloud protocols (see Van Den Haak et al. (2003), for a comparison of concurrent and retrospective think aloud protocols). This was especially significant as Koji's Quest aims to develop cognitive skills, and therefore adding an additional cognitive load (talking about the experience concurrently) was likely to affect game performance.

Prior to the think aloud protocol, participants were given a brief introduction to using VR and Koji's Quest, and then given the opportunity to try the game for 15 min. Game play and voice were recorded. Prompts (e.g., What were you thinking? How were you feeling?) were used to encourage participants to think aloud. As this was retrospective, the video was paused or rewound briefly to allow participants to expand, where necessary. Think aloud protocols were audio recorded and transcribed. Following the think aloud protocol, participants were given a verbal debrief.

2.3.2. Adult participants

In order to understand adults' experiences of VR EF training, a focus group was chosen. This was chosen to elicit not only about individual responses, but also shared responses about the utility of VR within an educational context.

Prior to the focus group, adults were given a brief introduction to using VR and Koji's Quest in small groups, and the opportunity to try the game for 15 min. Following this, participants took part in a focus group, focusing on participants' experience. The focus group was video recorded and transcribed. Key questions were used to elicit discussion, including 'tell me about your experience?' and 'what was memorable about this experience?' Anonymous SUS questionnaires were also used to assess ease of use and perceived confidence with technology levels. Following this, participants took part in a verbal debrief.

2.4. Analysis

Analysis focused on children and adults as two separate participant groups. In order to understand children's experiences, a thematic analysis of children's think aloud transcripts was completed. In order to understand adults' experiences, a quantitative analysis of SUS questionnaires, including Bangor et al.'s (2008) adjective and acceptability ratings was completed, in addition to a thematic analysis of focus group transcripts.

Think aloud protocols and focus groups were transcribed and cross-checked for accuracy. Thematic analysis of both children's and adults' responses included phases of analysis: familiarisation, generation, searching, reviewing, defining, as defined by Braun & Clarke (2021). Transcripts were first read and re-read, and initial codes noted, using NVivo software. Drawing on Hassenzahl's (2007) hedonic/pragmatic model of user experience, analysis was structured around the participants' perceptions of 'doing' and 'being'. A reflexive thematic analysis (Braun & Clarke, 2021) considered perception of use at a semantic level, and themes were considered prevalent based on either the number of instances and/or the number of different speakers. Similar codes were collapsed and themes generated: these were then reviewed to ensure consistency with participant transcripts. Themes were discussed and refined by two other researchers.

2.5. Reflexivity

The first author conducted the think aloud protocols and the focus groups. They had prior professional experience in education but had no prior relationships with the schools or individuals participating in the study. The research team adopt a critical realist approach to this research topic, which posits that although an independent reality exists, this is not accessible through direct observation and is impacted and limited by the conceptual frameworks though which we view the world (Fletcher, 2017).

3. Results

3.1. Children's experiences

Findings are presented under three broad themes: physical responses, perceptions of presence, and perceptions of game play. The responses of the child participants appear to illustrate an accumulative experience. The layers of experience: physical, presence, and game play appear to build one upon the other, whereby the higher needs (e.g. problem solving) can only be addressed when the lower needs (e.g., physical comfort) have been met.

3.1.1. Physical experience

The children's responses to physical experience were quite limited, but there appeared to be a consistency within this group. All children reported that the HMDs were comfortable, and there were no reports of them feeling too heavy. Some participants did report experiencing brightness when removing the headset; "when I took it off it was really bright" (C5). Other physical responses described were situated within descriptions of competence. For example, when describing a game, one participant commented "[it] felt like I needed to go quick and move" (C8). At other times these were linked to perceptions of confidence:

It felt weird like, cause I've never done anything like that before. Yeah, it felt weird … then when I started to realise what was going on and started to learn how to play the game … I felt a bit more confident with it (C1).

Typically, the physical experience of children was characterised by ease and comfort. Many children did not initiate feedback about the physical experience; when asked directly they were most likely to report it as being "comfy" (C4). Interestingly, the responses relating to this level were most frequently allied specifically to gameplay, and the need for a rapid physical response to the visual stimuli in the game. For example, one participant commented about the need to "Move my arm really quick [because] they're just tiny glimpses" (C8). Another participant described it as "you're moving your hands and it feels like you are interacting literally with this" (C6). Children's perceptions of presence were seemingly connected to the ease with which they responded to the physical experience and were discussed in terms of being active, which resonates with the wider discussion about how to define presence (Skarbez et al., 2017). In effect, their perception of presence was linked to what it enabled them *to do*. The ease of the physical experience seeped into their perceptions of presence in a way that allowed them to be active users.

3.1.2. *Perceptions of presence*

Children's perceptions of presence were depicted as an experience of fiction. Participants reported the sensation that although what they were experiencing was in some ways convincing, they knew it was not real. Although children described feelings of being immersed, these were countered by an expressed awareness of its *un*reality, for example "it wasn't real life, but it still felt like the same as real life" (C4). The examples that children used, of television and film, indicated that they were aware of the fictional nature of the experience, for example "it's like … I'm in the TV" (C1).

Consistent with their perceptions of presence the values they assigned to the experience were linked to being active. Children reported enjoying "how you could choose what game you wanted to do" (C7) and enjoyed navigating between the different environments within the game. They saw value in the game's capacity to give the user a choice over what they did and where they went. Some of the participants referred to this as a 'map' which then helped them to navigate to different places. They reported enjoying a sense of agency, for example, "I really liked it when like you got to like choose and you got to like, you had to like, memorise stuff … that was really fun" (C4). A more nuanced understanding of how presence is experienced by children, may therefore have implications for how this technology is implemented.

3.1.3. *Perceptions of gameplay*

Children's perceptions of game play were consequently linked to the value they assigned to this experience. Perceptions of gameplay were often centred around problem solving and their understanding of the aims of the games. The deliberately brief introduction to VR had included no instructions about the games themselves, and consequently, participants needed to problem solve to work out what to do and how to do it. For children, the problem solving was explicitly expressed: "I just sat there for a moment. Obviously, I gave it a minute and then I got a few tries wrong. And then … I gave it a little go" (C7).

Children commented, for example, on their initial experiences of the games, and how to work out the aims and functions. This included elements of problem solving, and children described the process of going from not knowing to knowing: "At that point I didn't really understand how to click the button, but then I figured it out, yeah" (C2). For some children, this involved some experience of trial and error, or waiting until the instructions became more explicit.

I got a few tries wrong. And then when I heard the do-do-o noise I was like, ohh yeah, I got one right. So, I kind of waited for the noise. I gave it a little go. And then I started to process that ohh, you had to add the gems up (C7).

Children's experience of gameplay was linked to their understanding of the games as meaningful for their education. Children were aware of, and wanted to know more about, what the games were designed to do, and this was considered a valuable feature of the experience. Children appeared to understand the combination of educational and entertainment features: "Yeah, I would like to play it again because it was entertaining, and I like working my brain" (C6).

Children also linked their perceptions of gameplay to the overall aims of the game, and showed awareness that the changing difficulty of the game was linked to what they would be able to achieve. Children expressed feelings about gameplay in terms of their own mastery (or lack of mastery) of the game. They also showed awareness of how the games were designed to help them make progress, for example "The difficulty sometimes varied, so sometimes the alien would be just an alien and a red block or something. And then another time it might be a smiling alien and a frowny alien. So, the difficulty varied" (C6). In another participant's words "The glass is full of water … you had to refill it, with the button. Then, you had more jobs to do" (C2).

Children's perceptions of gameplay were often linked to their awareness of the changes in game difficulty. For example, "I remember it as I was doing bad most of the levels. Believe it gives you the stats at the end of how you did and the first one, I believe it said 80% accuracy" (C8). This was also sometimes specifically linked to perceptions of self-esteem: "I did like the fish task, which I wasn't very good at when it got faster" (C5).

3.1.4. *Summary*

The responses of child participants indicate clear and meaningful links between the different levels of experience. A clear pathway becomes evident: the participant experiences physical ease; the participant experiences feelings of control and mastery; the activity is valued as cognitively and educationally meaningful; the participant experiences perceptions of competence. In short, descriptions resonate with usability 'doing' goals (Hassenzahl, 2007).

3.2. *Adults' experiences*

3.2.1. *System Usability Scale*

Seventeen adult participants completed the System Usability Scale (SUS). SUS scores ranged from 42.5 to 100 ($M = 71.47$, $SD = 18.6$). When using the Bangor et al. (2008) rating scale this indicated acceptable usability experience and in the context of the Bangor et al. (2009) rating scale it indicated a good usability experience. See Fig. 2 for the distribution of ratings across participants.

3.2.2. *Focus groups*

The responses of adult participants were less homogenous, however there was still evidence of meaningful links between the different layers of accumulative experience. However, in places, they appear to illustrate a failure to meet needs. This is especially true at the layer of physical experience.

3.2.2.1. Physical experience. The physical experience of adult participants was comprised of points of similarity and difference. For example, there appeared to be agreement between adult participants about the effect of VR on the eyes. This was primarily something that was reported about the end of the experience, and provided a description of the transition from the virtual world, back to the 'real' world: "It was literally just taking it off. I think it's maybe the process of suddenly lights being there and people being there" (A3). This was also an effect that was described as a behavioural response in terms of the capacity of the activity to grab attention: "But I felt like I was like staring the whole time. And I feel like even from after that, like my eyes feel a little bit dry" (A6).

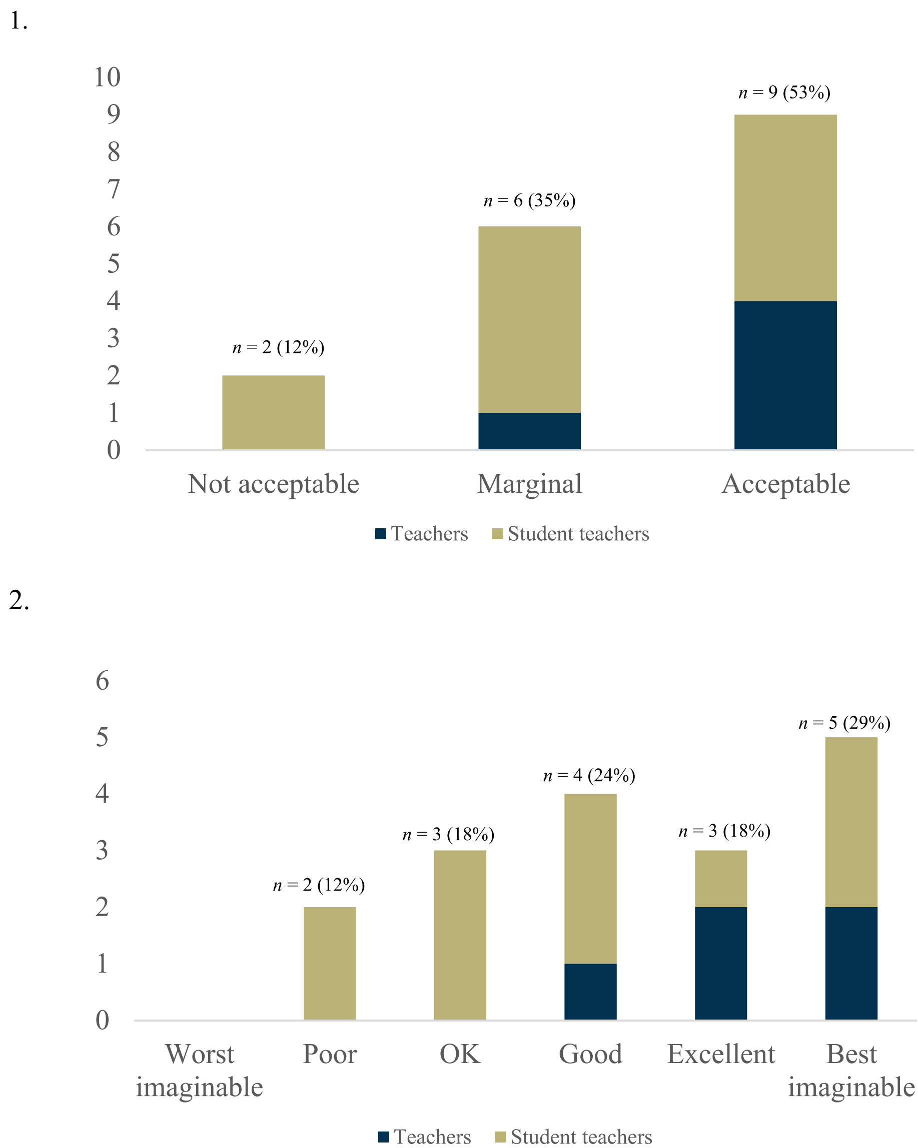

Fig. 2. Frequency of participants by (1) SUS acceptability and (2) adjective ratings, reflecting the differenecs in adults' perceived usability of VR.

However, there was disagreement within the adult group on a further element of the physical experience. There were strong opposing views about the weight of the HMD, with some participants reporting that it had felt comfortable, and that they hardly noticed it, with others reporting that the HMD felt very heavy and cumbersome. Some participants explicitly expressed concern about how children would cope with the experience; "I can't get over how heavy it is and how like, seems a lot for their little heads" (A6). In contrast, some were highly confident that the experience would be beneficial and appropriate for children; "The headset was very comfortable, and these were obviously easy to use … The children's not gonna be too difficult for them to use them" (A8). Differences within the adult group persisted throughout the subsequent layers of experience. It is noticeable that those participants expressing concern at this level appear to perceive the experience less positively in terms of presence, value and gameplay. The physical experience is crucial here, as this may impact later judgements about the suitability of this technology.

3.2.2.2. Perceptions of presence. Consistent with the findings about physical experience, there was some disagreement between adult participants in terms of their perceptions of presence. For some, perceptions of presence were characterised by feelings of relaxation. This manifested itself in terms of perceptions of time, physical sensations, and awareness of others: "I felt fully immersed. Every time I heard someone speak, I was like, ohh. I just felt so relaxed and calm. I could be here for hours" (A1). Another participant commented "Once I was in it … I was just in my game. Like when they called my name on the radio. It took me a minute to be like ohh, I need to concentrate, that's my name" (A13).

Some adults also ascribed value to it in terms of its capacity to separate the individual from the world around. This was considered valuable in terms of how relaxing the experience could be, but also how beneficial it could be to support children in terms of their attention. "I think I just tuned out. I was so focused on the waterfall. And the ripples in the water and the trees moving. I think I just, I was completely in the zone" (A8). It is notable that these values were different to child participants. Whereas child participants assigned value to the experience in what it enabled them to *do*, adult participants appeared to assign value to the experience in terms of what it enabled them to *feel*.

For others, perceptions of presence were associated with feelings of being separated and isolated from the 'real' world. For these participants there was a very strong sense of being somewhere else, to the extent that it was able to change their behaviour; "I'm still sort of adapting to being out of that and coming back into this, even though it had been a couple of minutes … Yeah, I forgot how to walk it's a bit, a little bit odd" (A3).

This was also linked to a more generalised concern about the effect that virtual worlds were able to have on them. For example, some participants reported that it “drew me in” (A12) and that they felt “kind of absorbed into it” (A14). For others, this effect was considered in more serious terms, and at these points, participants drew links between perceptions of presence and digital addiction. For example, “I think one thing about it is like with increasing digital addictions and stuff is that part of that is isolation and, you know, blocking out the world. And that’s the most literal extreme from technology” (A7). The diverging physical experience of the adult group apparently continues at the level of perception of presence. Although there was agreement in the description of VR as taking you to a different space, the nature of this place varied. For those comfortable with the physical experience this was perceived as safe and inviting. For those uncomfortable with the physical experience, it was perceived as threatening.

3.2.2.3. Perceptions of gameplay. Adults’ perceptions of gameplay were rooted in their descriptions of physical experience, and technology use. For example, some participants explained that they had found it difficult to work out how to interact with the game, or to understand what they needed to do. For example, “I couldn’t figure out what it expected me to do, how it wanted me to do it” (A11). They went on to comment:

> I think it may have been the one where … the numbers were hanging down from the trees, with the dog. I can’t remember what it was called. But that was, yeah, I knew what to do and I could see it, but there wasn’t any way of clicking on anything to get instructions, which some children do need (A11).

Their perceptions of gameplay were also closely linked to the physical experience of playing the game in a VR environment. For some participants, this was described as a physical disconnection between their own bodies, and what they were able to achieve in the virtual world.

> I found it quite hard sitting down and doing it though, I think because. I couldn’t work out how to move like as in I know that sounds really silly, but I couldn’t work out if I was meant to like move the little like little things on it on the controller. And I was trying to move, and I can’t understand. But once I got the hang of actually just having to click on things, I was like oh this is how I do it. But I think because I felt like I could see my hand, like I could see like my arm on the game and stuff, but I couldn’t work out how to move to. I could just see the controllers (A5).

3.2.2.4. Summary. The responses of adult participants were less homogenous, however there was still evidence of meaningful links between the different levels of experience. For some participants, physical discomfort was linked to feelings of loss of control and isolation; linked to a devaluation of the activity; linked to perceptions of gameplay that are deemed irrelevant. For others, physical ease was linked to feelings of relaxation; linked to valuing the activity as meaningful; linked to perceptions of competence. In short, descriptions resonate with usability ‘being’ goals (Hassenzahl, 2007).

4. Discussion

4.1. Motivation

The child and adult participants demonstrate a different emphasis between the three elements of self-determination (Ryan & Deci, 2000) which is perhaps reflective of both fundamental attitudes to the educational context, wider social narratives about technology and prior technological experience (Fig. 3). These findings suggest that younger users are more likely to describe the experience in terms of autonomy and competence, whereas adult participants are more likely to describe the experience in terms of relatedness.

Fig. 3. Illustrative quotations corresponding to the elements of autonomy, competence and relatedness from child participants (C), and adult participants (A).

For child participants, autonomy was expressed through the sensation of *interacting* with the virtual world. Child participants appeared to value this sense of interaction. Autonomy needs were only referred to by the child participants and this is arguably reflective of the inherent power bias between school staff and children within the educational context. Those who hold positions of responsibility in a school inevitably make decisions about how time is spent on behalf of children. Within this context, autonomy needs are arguably more salient for children, and therefore more likely to form part of their narrative of experience. Therefore, when considering utilising VR based training protocols within the educational setting autonomy needs to be an important consideration.

For child participants, competence was expressed through the awareness of the function of the game, but it was also evident in their awareness of how well they were mastering the game. In contrast, for adult participants, competence was expressed primarily about the use of the technology; how the equipment enabled them to function in the virtual world. Although both adults and children focused upon competence, there were significant differences between them. For children, competence was expressed through their experience of the game; for adults it was expressed through their experience of the technology itself. Arguably, this could be seen as indicative of the relative ease with which children adapt to new technology. For adults, the process of learning a new technology was meaningful *in itself*. For children, the process of learning a new technology did not warrant explanation or description: what was important to them, was what the technology enabled them *to do*. Again, this has important implications for the different ways in which children and adults may need to be trained in this technology.

Interestingly, child participants made no reference to the way in which the experience was connected to relatedness needs. For adults, relatedness was expressed both in positive terms and negative terms. For example, it was discussed in terms of how VR can be used to engage students and create supportive environments, but also in terms of how it might detract from relationships. There are two potential reasons for this discrepancy that warrant further attention. Firstly, it is arguable that as all educational experiences are inherently social, children did not identify the VR experience as being any different. In this sense, relatedness needs for children are already being met through the relationships they have with staff and peers. It is arguable that the precise activities would only be meaningful if relatedness needs were deficient. Secondly, it is possible that adults' focus on relatedness is an outcome of increased exposure to social narratives about technology (Liu & Szabo, 2009). There is currently frequent media coverage about the potential dangers of technology as well as increased current concern about children's mental health, specifically as a result of the COVID pandemic (Putra et al., 2023; Şenol et al., 2024). Social narratives frequently draw upon the alienating effects of technology, and it is plausible that adults have been exposed to these more than children.

These potential differences between children and adults underline the relevance of both SDT and CAMIL within this context. Both adults and children demonstrated the importance of perceptions of competence, as theorised in SDT. Although these perceptions derived from different aspects of the same experience, the prevalence of this theme across both groups would seemingly provide support for competence as an essential component of motivation.

4.2. Usability

Hassenzahl's model of user experience (2007) divides the experiences of users into pragmatic and hedonic experiences. The pragmatic and hedonic experiences are characterised as separate, meaning that users typically perceive these experiences as being independent of each other. This research finds evidence for a relationship between the pragmatic and hedonic experience, but not a hierarchy. For both children and adults, these two elements of the VR experience were seemingly connected.

Unsurprisingly, the 'be-goals' of the children were different to the adults. Children's 'be-goals' tended to be based around being autonomous, and these were typically met through 'do-goals' of making choices or solving a problem. The variety of responses linked to different aspects of motivation are potentially indicative of an experience that can meet a variety of needs. Crucially, children were very able to articulate where these needs were being met.

In contrast, adults' 'be-goals' appeared to be based upon caregiving. This was evident through the descriptions of student-motivating experiences, and opportunities for mindfulness. How, and whether this goal was met, varied between individuals. For some adults, this was met through 'do-goals' of relaxing. For others, this was *not* met through the 'do-goals' of protecting the children. However, for the adult participants there is also evidence of the pragmatic experience impacting the hedonic experience. This is a departure from the pragmatic-hedonic model, which positions the hedonic experience as higher-order. For adults, differences between individuals in terms of the pragmatic experience appeared to be linked to differences in the hedonic experience. In short, those who had a positive pragmatic experience (for example, reporting confidence with what they were able to do with VR) typically linked this experience to meeting hedonic goals (for example, the opportunity to be more engaging with their students). In contrast, those who had a less positive pragmatic experience (for example, reporting a lack of confidence with what they were able to do with VR) typically linked this experience to *not* being able to meet hedonic goals (for example, not being able to safeguard their students). Rather than a hierarchical relationship between the pragmatic and hedonic experiences, this evidence seems to suggest a transactional relationship, where the experiences build upon each other to gradually construct meaning.

The differences within the adult group are further supported by the findings from the System Usability Scale. When applying the adjective rating (figure 2), although four participants reported the experience as 'good', there were extremes of experience of both 'poor' and 'best imaginable'. The lack of consensus within the adult group suggests that a wider range of factors may be influencing the usability experience.

4.3. Presence

The difference aspects of SDT and usability discussed above have the potential to impact the experience of presence within the VR environment, an important consideration given it is one of the unique affordances of the VR environment and one of the main justifications for changing media. For child participants, experiences were defined in a way that suggested a perception of presence that involved doing, as well as being. For child participants, experience was less about what it felt like, but what it enabled them *to do*. For adult participants, experiences were defined in a way that suggested a perception of presence that enabled them to *be*. Within education, this may mean that those in charge of delivering a VR experience (the teachers) may be experiencing it quite differently to those they are delivering it to (the children). The distinction made by Skarbez et al. (2017) between active and passive definitions of presence appears particularly relevant here, and points to the possibility that definitions of presence may need to be more clearly defined by age.

Of course, in the context of delivering VR EF training, definitions of presence become highly significant. In this qualitative sample, children's descriptions hint at a relationship between presence and increased engagement with the activity. This, however, stands in contrast with other research (e.g., Huang et al., 2020), that suggests that higher levels of presence may decrease engagement with the activity.

These findings also stand in support with the CAMIL framework, which suggests that the unique affordance of presence impacts the individual in terms of self-efficacy and motivation. For child participants, their perception of presence as 'doing' was presented as a motivating factor; for adult participants, their perception of presence as 'being' was presented as de-motivating.

5. Contributions

5.1. Theoretical implications

They also suggest that, in line with prior research (Makransky et al., 2019) children experience VR as a motivating tool, and that therefore it may be efficacious in supporting a range of educational aims, including EF training. There is potential for VR to create environments which support active learning opportunities, which are likely to foster high levels of agency and engagement. The differences between the experiences of adults and children, however, highlight the need for a greater understanding of how children perceive and respond to this technology. The distinction made by Skarbez et al. (2017) between active and passive definitions of presence appears particularly relevant here, and points to the possibility that definitions of presence may need to be more clearly defined by age.

5.2. Application

This research suggests that teacher training about VR should emphasise and establish a significant level of physical comfort from the outset. For some individuals, more time may be needed to establish a level of familiarity that is then amenable to further exploration. Without this, individuals are more likely to be 'stuck' in the physical experience, and less likely to progress to perceptions of competence. Where individuals are less comfortable with new technology, they are more likely to utilise them in a way which limits risk. For example (Liu & Szabo, 2009), has suggested that teachers who are less confident will use technology to demonstrate teaching, rather than empowering children to use it for themselves. Teachers' perceptions of safety in the context of technology warrant further examination, and it is likely that this is an area to be tackled by individual schools. All schools are compelled to have stringent safeguards in place for children and this includes accessing technology. It is reasonable for those with responsibility for children to have clear guidelines about the ways in which children could be put at risk when accessing VR technology. A clear understanding of the ways in which risks can be mitigated, alongside the competency to ensure safeguards are in place, will support staff to grow in competence and confidence.

6. Conclusions

These results suggest that, in line with prior research (Makransky et al., 2019) children experience VR as a motivating tool, and that therefore it may be efficacious in supporting a range of educational aims, including EF training. There is potential for VR to create environments which support active learning opportunities, which are likely to foster high levels of agency and engagement. The differences between the experiences of adults and children, however, highlight the need for a greater understanding of how children in particular perceive and respond to this technology.

6.1. Limitations

Whilst it was important to consider the experiences of children and adults within an educational context, it is very difficult to extricate individual responses from the potential influence of social roles. For both adults and children, there are certain expectations that are implicitly reinforced within a school context. For example, with the adult's role of gatekeeper, it is unclear whether the responses of adults were given truly about their own experiences, or whether they were projecting what they anticipated children would say. There is also the influence of hierarchy within groups of adults, which may have encouraged some narratives to be heard more than others. With the adults who were working within the school, there is the influence of wider school policies and attitudes, towards technology specifically, and change more generally.

There is also the inherent difficulty of ensuring that the voices and opinions of children are genuinely heard. Although great care was taken to ensure that child participants felt comfortable, that they understood that there were no 'right' answers and that all opinions were valuable, there is no guarantee that their responses were not, at least in part, impacted by the inevitable power imbalance between child participant and adult researcher.

Finally, given that the use of EF training in an education has applications across a diverse range of students, an important limitation of the present study is the small sample size; further research is certainly required to explore the potential differences in how adults and children experience VR. It would be useful for this research to focus on a diverse population both in terms of age and prior experience with technology.

6.2. Future directions

Increased availability and affordability of VR technology means that educational application is now a feasible reality. It is therefore essential to fully understand the VR experiences of both children and adults. Understanding the experience of the child can support education providers to fully exploit the educational benefits of this technology in a way that will motivate and inspire children to learn. Understanding the experience of the adult can support education providers to provide training which is effective and meaningful regardless of previous technological experience. Future research should focus on experience over a longer duration, as this is truly where technology has a place in education: as a long term tool for intervention.

These results suggest that children experience VR as a motivating and useable tool, and that therefore it may be efficacious in delivering EF training. However, one of the key features of cognitive training is that it often requires participants to persevere over a long duration. Research has demonstrated that the overall number of minutes of training is a factor in overall effectiveness, and therefore it is essential that participants want to continue and persevere with the training. Cognitive training interventions often report relatively high rates of attrition, and this is something which can weaken its overall effectiveness. Although this research demonstrates the potential of VR to provide a motivating experience, the relationship between motivation and educational outcomes is complex (e.g., Makransky & Petersen, 2021). Therefore, when considering VR as a media to deliver training the next step will be to examine its implementation within an educational setting, both with regard to its effectiveness at improving EF and secondly its impact on motivation across multiple training sessions.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2024.100500.

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