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REVIEW ARTICLE

Social Skills Training Using Virtual Reality in High Functioning Autism Spectrum Disorder: A Systematic Review

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ABSTRAK

Individu dengan gangguan spektrum autisme berfungsi tinggi (HFASD) merupakan mereka yang berada pada tahap yang lebih ringan dalam spektrum gangguan autisme (ASD). Walaupun ia mungkin tidak ketara, mereka menghadapi kesukaran serta cabaran dalam kemahiran dan interaksi sosial. Kaedah tradisional latihan kemahiran sosial, yang memfokuskan pada intervensi secara bersemuka, sering kali kurang menarik dan sukar digunakan secara meluas. Kajian terkini menunjukkan bahawa realiti maya (VR) boleh menjadi alat yang berkesan untuk meningkatkan kemahiran sosial dalam individu autisme. Tinjauan sistematik ini bertujuan untuk menilai keberkesanan intervensi VR yang direka khusus untuk latihan kemahiran sosial dalam kanak-kanak dan remaja dengan HFASD. Carian secara menyeluruh telah dilakukan melalui pangkalan data PubMed, Cochrane, Scopus dan Embase untuk mengenal pasti literatur yang berkaitan. Sebanyak enam kajian yang menggunakan teknologi VR bagi latihan kemahiran sosial autisme berupaya tinggi dan diterbit dalam Inggeris telah dikenalpasti. Kajian-kajian tersebut memenuhi kriteria carian. Penemuan menunjukkan bahawa intervensi berasaskan VR menunjukkan potensi dalam meningkatkan kemahiran sosial, kerana semua kajian melaporkan peningkatan yang signifikan dalam kemahiran sosial yang disasarkan seperti interaksi sosial, kognisi sosial dan komunikasi bukan lisan. Kesimpulannya, walaupun penemuan dalam ulasan ini menunjukkan hasil yang memberansangkan, bilangan kajian yang layak yang agak terhad tidak dapat membuktikan keberkesanan pendekatan tersebut untuk latihan kemahiran sosial. Kajian lanjut dengan reka bentuk kajian yang lebih ketat dan ukuran hasil yang diseragamkan diperlukan untuk menentukan keberkesanan intervensi VR untuk latihan kemahiran sosial di kalangan individu dengan HFASD.

Kata kunci: *Autism; gangguan autisme berfungsi tinggi; latihan kemahiran sosial; realiti maya*

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ABSTRACT

Individuals with high-functioning autism spectrum disorder (HFASD) are those who are at the milder end of the autism spectrum disorder (ASD). Although it may not be apparent, they struggle with social skills and face challenges in real-world social interactions, such as difficulty reading others' emotions and social cues. The traditional social skills training methods, which focus on face-to-face interventions, often lack of engagement and generalisability. Virtual reality (VR) has emerged as a promising tool for addressing social deficits in these individuals. This systematic review aims to evaluate the effectiveness of VR interventions for social skill training in children and adolescents with HFASD. A thorough search was conducted in PubMed, Cochrane, Scopus and Embase databases to identify the relevant literature. A total of six studies that utilised VR technology for social skills training in high-functioning autism and were published in English were included. These studies met the search criteria. Findings suggest that VR-based interventions show promise in improving social skills, as all studies reported significant improvement in targeted social skills such as social interaction, social cognition and non-verbal communication. In conclusion, despite the promising findings in this review, the relatively small number of eligible studies could not conclusively ascertain the effectiveness of such an approach for social skill training. Further research with rigorous designs and standardised outcome measures is warranted to establish the efficacy and optimal implementation of VR interventions for social skill training in individuals with HFASD.

Keywords: Autism; high-functioning autism; social skill training; virtual reality

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterised by pervasive impairment in communication, behaviour and social functioning with varying levels of severity (Ministry of Health Malaysia 2014). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), classifies ASD based on the severity of symptoms and the level of support required in social communication and restricted, repetitive behaviours, ranging from Level 1 (requires mild support) to Level 3 (requires very substantial support) (American Psychiatry Association 2013). For example, individuals with ASD who are classified as having Level 1 severity and possessing normal intelligence (IQ) are often referred to as having high-functioning autism (HFA), although this is not an official DSM-5 term (Hui 2020). Individuals with ASD hold varying degrees of intelligence; average or above-average intelligence is considered high-functioning autism spectrum disorder (HFASD), while below-average intelligence is considered low-functioning autism (Fauziyah et al. 2020). Although all individuals meet the core diagnostic criteria, functional estimates remain highly variable. Meanwhile, HFA is a term used to describe individuals with ASD and an IQ of 70 or higher (Alvares et al. 2020). The term "Asperger Syndrome," coined by Hans Asperger in 1944, was also being used interchangeably with HFA, but the diagnosis was placed under ASD in DSM-5 (Barahona-Corrêa & Filipe 2016; Tsai & Ghaziuddin 2014). Despite their differences, such as language difficulties and cognitive profiles, ASD is a more preferable term as it encompasses a spectrum of experiences with varying degrees of severity and a wide range of associated

characteristics (de Giambattista et al. 2019; Molla & Hosseini 2024; Ozonoff et al. 1991). These individuals may have significant social and communication difficulties, but they are often able to communicate effectively and may even live independently with some support (Baron-Cohen 2000; Blacher et al. 2003).

While the severity of symptoms can vary widely among individuals, those with HFA often face significant difficulties in navigating social situations and may require support or intervention to improve social skills and functional outcomes. The lack of social skills can lead to major challenges that affect their mental health and quality of life (Burgess & Turkstra 2010; Lawson et al. 2020; Tebartz van Elst et al. 2013) and can even lead to depressive or anxiety disorder later in adulthood (Hollocks et al. 2019).

While there is no known cure for ASD, social skills training is an essential intervention for individuals on the spectrum, particularly those with HFA. Effective social skills are crucial for building and maintaining positive relationships, collaborating with others, succeeding in academic and professional settings, and participating fully in social and community life (Bellini & Peters 2008). These skills are developed through learning, observation, practice and feedback from social interactions and may vary in complexity and proficiency across different individuals and contexts (Elliot & Gresham 1993; Szatmari et al. 1995). Individuals with HFA not only struggle with social skills but also exhibit challenges in planning, organising, and multitasking (Mackinlay et al. 2006).

Traditional interventions for social skills training, such as group therapy and role-playing, have shown limited effectiveness due to issues with engagement, generalisation of skills to real-world settings, and acceptability among individuals with HFA (Gresham et al. 2001). A meta-analysis of school-based social skills training programs showed only minimal effectiveness for children with ASD (Quinn et al. 1999).

Virtual reality (VR) offers a unique platform for delivering interventions tailored to the specific needs of individuals with ASD, including those with HFA (Lee et al. 2023). It is a technology that creates an immersive virtual environment, providing a sense of physical presence through screens or head-mounted displays (HMDs) in three forms, namely non-immersive, semi-immersive and fully immersive (Hamad & Jia 2022; Kouijzer et al. 2023; Musa et al. 2020). Moreover, VR provides interactive, and customisable environments that simulate real-life social situations in a controlled and safe manner (Dechsling et al. 2021). These features hold promise for enhancing engagement, facilitating skill acquisition, and promoting the generalisation of learned behaviours to real-world contexts, as reported by many studies (Frolli et al. 2022; Newbutt et al. 2016; Newbutt et al. 2020). However, research has been inconsistent regarding the efficacy of VR interventions for social skills training among individuals with ASD, particularly those with HFA (Halabi et al. 2017; Sarah & Peter 2002; Yuan & Ip 2018). Furthermore, one particular research denied any significant differences between conventional face-to-face training and behavioural intervention technologies, which include VR social skills training (Halabi et al. 2017). Additionally, several researchers have outlined the benefits of VR training for people with ASD over alternative methods (Yang et al. 2016).

While several studies have explored the use of VR for social skill training in individuals with ASD, there is a need for a systematic review focusing specifically on its application in the high-functioning autism population. This

review aimed to evaluate existing evidence on the effectiveness of VR interventions for social skill training in individuals with HFASD, identify gaps in the literature, and provide recommendations for future research and clinical practice. We hypothesised that VR training is effective for social skills training in children and adolescents with HFASD.

MATERIALS AND METHODS

Search Strategy

A systematic search according to PRISMA guidelines in the electronic databases, including Cochrane, PubMed, Embase, and Scopus, was conducted from 16th July 2023 to 29th February 2024. The following keywords were used to search in PubMed: ((virtual reality[Title/Abstract]) OR (VR[Title/Abstract]) AND (social skills training[Title/Abstract])) OR (social training[Title/Abstract])) OR (social skills exercise[Title/Abstract])) OR (Social skills[Title/Abstract])) OR (social cognition training[Title/Abstract])) OR (social training[Title/Abstract]) AND (autism spectrum disorder[Title/Abstract])) OR (High functioning autism[Title/Abstract])) OR (ASD[Title/Abstract])) OR (HFASD[Title/Abstract])) OR (Asperger[Title/Abstract])) OR (Asperger syndrome[Title/Abstract])). The search was restricted to articles, abstracts, reviews or case reports.

Study Selection

Studies were included if they met the following criteria: (i) participants diagnosed with high-functioning autism or Asperger's syndrome; (ii) intervention utilising any form of VR technology for social skill training; (iii) age must be less than 18 years old during the study period; and (iv) published in English-language peer-reviewed journals. The exclusion criteria included: (i) non-published articles; (ii) participants more than 18 years old; (iii) intervention other than VR; (iv) intervention that targets other than social skills training; and (v) studies that were written in other languages. There was no limitation in terms of publication years.

Selection Process

All the search results were exported to the reference management software Covidence ("Covidence Systematic Review Software" n.d.). The software automatically took out all the duplicate studies. Two independent reviewers (MAA and NIAT) screened titles and abstracts for eligibility. After obtaining the complete texts of the selected records, two independent reviewers assisted in applying the PICOS framework to determine the records' eligibility. Any doubts or conflicts were resolved by discussion with a third reviewer (CSK).

Study Quality

We assessed the quality of each included studies according to the Critical Review Form for quantitative studies from McMaster University (Law et al. 2007). Each question was rated "Yes", "No", "Not addressed", or "Not Applicable". Every "Yes" answer was given a score of 1 point, and the overall score differed depending on the study design. The intervention category of the Australian National Health and Medical Research Council (NHMRC) evidence hierarchy was used to assess the level of evidence of the included studies. (Barratt 2000).

Data Extraction and Synthesis

Relevant data, including study design,

participant characteristics, VR intervention details, outcome measures and key findings, were extracted independently by two reviewers. Any discrepancies were resolved through discussion or consultation with a third reviewer.

RESULTS

The initial search from the four databases (Scopus, Cochrane, PubMed and Embase) yielded a total of 24451 studies, and 1705 duplicates were removed. Only 69 studies were able to meet the inclusion criteria after screening titles and abstracts. The full text of these studies was reviewed, and 62 studies were excluded because of the following reasons: (i) intervention other than VR (25 studies); (ii) not population of interest (13 studies); (iii) not outcomes of interest (13 studies); (iv) not the indication of interest (2 studies); (v) the rest were still ongoing study (5 studies); and (vi) no full text available (4 studies). Attempts to obtain the full texts by contacting the authors and the institution via email were unsuccessful, as no response was received. A total of six studies were included (Table 1). The included studies were varied in design, with one randomised control trial (Zhao et al. 2022), four single-group pre-post intervention studies (Cheng et al. 2015; Didehbani et al. 2016; Ke & Lee 2016; Serret et al. 2014) and one non-randomised single-arm control trial (Abdelmohsen & Arafa 2021). Sample sizes ranged from 2 to 44 participants, with a total of 127 individuals with high-functioning autism across studies. The age ranged from 3 to 17 years old. Thus, only six studies were included in this review (Figure 1). Despite having four pre-post intervention studies, we could not do meta-analysis due to the heterogeneity of the study design and outcome measure. The results were summarised in Table 1.

DISCUSSION

In this review, the VR interventions were diverse, encompassing virtual environments targeting various social skills such as emotion recognition, imitation, conversational skills, and social problem-solving. The duration and intensity of interventions varied, ranging from several sessions to multi-week programs. Outcome measures also varied widely, including standardised assessments, observational measures, and self-report questionnaires.

There are two types of studies included in this review: controlled trials and pre-post intervention studies. Of controlled trials, only one is a randomised controlled trial (RCT). Acknowledging the novelty of the field, it is understandable that RCT remains scarce. Even though pre-post intervention studies did not have the same statistical power as RCT, it is still valuable to expand and enrich the concept of VR as a part of treatment in HFA. There are a few possible reasons for limiting the number of RCTs: the massive resources needed, the ethical dilemma of excluding potential beneficiaries from receiving their intervention and the lack of a suitable substitute for a placebo.

Another interesting point to be noted is the target age group for each intervention. Of these six studies, only two studies involved a younger age group, from 3 to 5 years old (Abdelmohsen & Arafa 2021; Zhao et al. 2022). This age group matters as these are the normal age range targeted for early intervention programmes (EIP)(Corsello 2005). Multiple studies have proved the benefit of starting the intervention at an earlier age in autism (Ben Itzchak & Zachor 2011; Zwaigenbaum et al. 2015). The rest of the studies were conducted at primary school age onwards. These may be conscious decisions by the authors due to certain elements of VR, which could be complicated for younger children to comprehend apart

TABLE 1: Characteristics of included studies

No	Author, Country	Type of Study	Age range, total of participants (n)	Inclusion criteria	Exclusion criteria	Intervention	Exposure measurement scale	Outcome measurement scale	Comparator / control	Statistics	VR intervention outcome	Quality Assessment using Critical Review Form for quantitative studies
1	Zhao et al. (2022), China	Randomised controlled trial	3 to 5 years old, n = 44	- Caregivers who were relatives of the children and aged 20-29 years with normal cognitive and reading abilities who agreed to participate in the study - Children diagnosed with ASD according to DSM-5 - Children aged 3-6 years who were stable and conscious patients	- Children diagnosed with other serious organic diseases - Children and caregivers who were participating in other investigations or interventions - Participants or caregivers who refused to participate or withdrew at any stage of the study - Other serious physical or mental diseases within the family	Collective class training, sensory integration training, fine motor training and VR training	VR training	Psychoeducational Profile, Third Edition (PEP-3), Chinese version	The control group only received conventional rehabilitation training.	Paired t-test for normal distribution data. Rank-sum test for non-parametric data.	The cognitive ability and social communication ability of the children in the intervention group were significantly higher than those in the control group ($P< 0.05$)	13/14 (93%)

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2	Abdelmohsen & Arafa (2021), England Non-randomised single-arm control trial	4-12 years old, n = 15	- Aged 4-12 years old - Diagnosed as HFASD with IQ > 70 - Verbal and could read simple words to be able to interact with the tool	Not described	- Laptop (computer) - Interaction with a virtual robot, Jammo Vrobot, through three phases -Phase I: provided training for emotion recognition and focuses on the basic six emotions -Phase II aimed at expressing emotions through imitation, -Phase III: for training emotion recognition and expression through storytelling	Nil	Gesture recognition skills of the participants - comparing the scores of the participants in the pre, post, and follow-up (delayed) tests (Questionnaire assessed the number of items each child correctly recognised the meaning of the gesture or provided proper gestures for the stories) Emotion Recognition and Expression Training Programme: -comparing the score -observation as qualitative data of the participants in the pre, post, and follow-up (delayed) tests to assess the ability to recognise the basic six emotions expressed by the Jammo VRobot -observation as qualitative data	Nil	Mean score	Gesture recognition skills of the participants: Pre and post test scores comparison in all phases demonstrated an increment. Recognition skills in phase I further improved in the follow-up test. In phase III, participants found the storytelling task the hardest. Emotion Recognition and Expression Training Programme: Pre and post-test scores comparison in all phases showed increased scores. The positive learning outcomes in all phases were maintained two weeks after the training.	10/14 (71%)

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3	Didehbani et al. (2016), USA Pre-post intervention study	7 to 16 years old, n = 30	Diagnosed with Asperger syndrome or Pervasive Development Disorder-NOS (using ADOS)	Acute psychiatric conditions or Axis 1 psychopathology or history of neurologic disorders	Virtual reality-based Social cognitive training program (VR-SCT)	10 one-hour virtual reality training sessions	1. Affect recognition - NEPSY-II Facial Affect Recognition and Ekman 60 2. Social attribution - Triangles Task 3. Attention and Executive function - NEPSY-II Auditory Attention and Response Set and Analogical Reasoning Task	Nil	Paired standard T-test, then used ANOVA to compare ASD only versus participants with ASD and ADHD.	Affect recognition: Significant increases on NEPSY- II Affect Recognition t (24) = -3.40, p = 0.001. Social attribution task: Significant improvement on the Triangles Internationality score t (23) = -2.28, p = 0.016. Attention and executive function: Significant increases in analogical reasoning t (17) = -2.33, p + 0.016, but no significant change on NEPSY-II Audioty Attention and Response Set. In all categories, there were no significant differences between ASD only and ASD with ADHD.	12/14 (86%)

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4	Cheng et al. (2015), Taiwan Pre-post intervention study	10 to 13 years old, n = 3	ASD with basic cognitive and reading abilities	Not described	3D-SU system (Virtual environment)	Social Event Card (SEC) that involved 12 events that could occur in the classroom and school environments	Social Behavior Scale (SBS) target three areas, namely Nonverbal communication (NC), Social Interaction (SI) and Social Cognition (SC)	A- Baseline phase B - Intervention phase C - Maintenance phase	Single-subject experiment with multiple-probe design	All participants demonstrated significant improvements in their social skills from baseline to intervention phase. The score remained consistent during the maintenance phase.	10/14 (71%)
	Ke & Lee (2016), America Pre-post intervention	8 - 11 years old, n = 3	Children with HFASD	Purposive recruitment was not clearly stated	Virtual world to build a virtual Japanese neighbourhood that was devastated by a tsunami earthquake	- Exposure to the virtual environment - Cooperative skills to reconstruct environment-time series -screen recordings-micro-behaviour	Mastery of communication and social skills	One normally developing peer	Qualitative taxonomy	Participants demonstrated a significant improvement in social flexibility and better social interaction.	11/14 (79%)

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6	Serret et al. (2014), France Pre-post intervention study	6 to 17 years old, n = 33	Diagnosed with ASD	Non-efficient use of the gamepad, refusal to play	JeStiMuLe game (individual VR multisensory game)	Usability assessment (Adaptability, effectiveness, efficiency)	Emotional recognition	Session (Pre vs post), Task (Facial vs gestures emotions), emotions (Happiness vs surprised vs sadness vs fear vs disgust vs anger vs pain)	ANOVA (multiple means)	Significant main effect of Session on avatars (ANOVA: F (1,32) = 98.48, P < .001) and on pictures of real-life characters (ANOVA: F (1,32) 49.09, P < .001). A significant Session Task Emotion interaction was also found for avatars (ANOVA: F (6,192) = 2.84, P = .01). This triple interaction was close to significance for pictures of real-life characters (ANOVA: F (12,384) = 1.73, P = .057). Post-hoc analyses revealed that 30 out of 35 conditions found a significant increase after training.	13/14 (93%)

ASD: Autism spectrum disorder ; ADHD: Attention deficit hyperactive disorder; ANOVA: Analysis of variance; DSM-5: Diagnostic and statistical manual of mental disorders, fifth edition; HFASD: High-functioning autism spectrum disorder; IQ: Intelligence quotient; NEPSY: Neurological assessment; 3D-SU: Three-dimensional social understanding; VR: Virtual reality

*Even though studies 4-6 participants were not diagnosed with HFASD in the study itself. Based on the papers, all the participants were assessed using the Weschler Intelligence Quotient test and they fulfilled the criteria of HFASD.

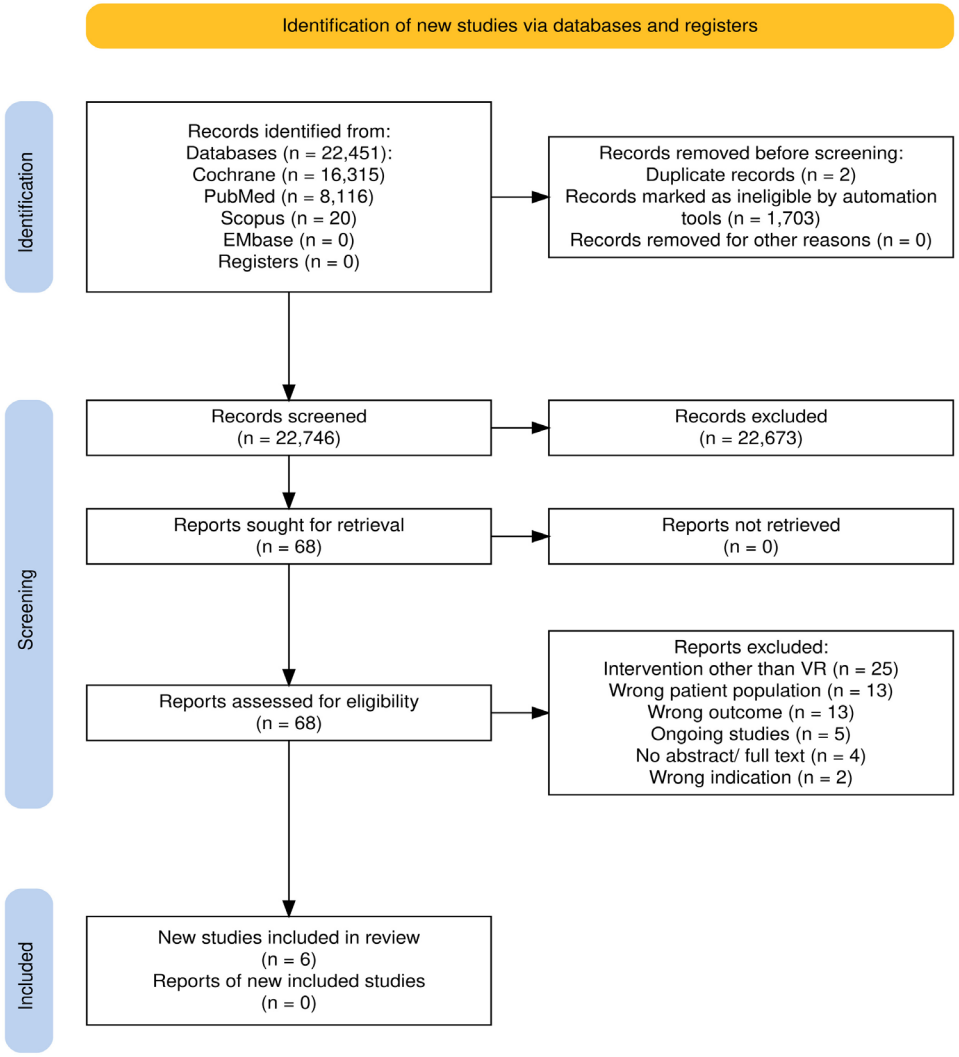

FIGURE 1: Systematic literature search, screening and relevance assessment conducted according to PRISMA guidelines

from being more nuanced, which could only be attained with experience. This also raised questions about the applicability of the system as a part of early intervention as well.

The majority of these studies implemented the virtual environment concept as part of their methodological framework (Cheng et al. 2015; Didehbani et al. 2016; Ke & Lee 2016; Zhao et al. 2022) while one study used the virtual robot (Abdelmohsen & Arafa 2021) and the other one utilised the gamification concept (Serret et al. 2014). The concept of a virtual environment may be more intuitive in improving social skills as they try to resemble real-life scenarios as much as possible (Bellani et al. 2011; Maskey et al. 2014; Wang et al. 2021). Virtual robot posed a different concept as the robot served as a friendly figure that was more accessible and receptive towards the needs of patients with HFA (Abdelmohsen & Arafa 2021). On

the other hand, gamification also could be a different strategy to attract attention and promote compliance.

As previously mentioned, VR has demonstrated significant potential in enhancing engagement and improving social skills training for individuals with HFASD. This was supported by three of these studies that found VR facilitated better engagement with the training programs (Abdelmohsen & Arafa 2021; Cheng et al. 2015; Ke & Lee 2016). Abdelmohsen and Arafa (2021) showed that VR robot are well-accepted and Didehbani et al. (2016) in their study proven that VR environment is well-accepted as it provides interactive and visually stimulating approach to help with the social skills training.

Overall, findings from the included studies suggest that VR interventions hold promise for improving social skills in individuals with HFA. All studies reported significant improvements in targeted social skills such as social interaction, social cognition and non-verbal communication following VR training compared to baseline or control conditions (Abdelmohsen & Arafa 2021; Cheng et al. 2015; Didehbani et al. 2016; Ke & Lee 2016; Zhao et al. 2022). Some studies also reported positive effects on the generalisation of skills to real-life settings and maintenance of gains over time (Didehbani et al. 2016; Ke & Lee 2016). In other studies, the virtual social robot that was used was cost-effective and user-friendly, not only for patients but also for parents to use either at home or at school (Abdelmohsen & Arafa 2021).

However, methodological limitations were evident across studies, including small sample size, lack of control group, and heterogeneous outcome measures. For instance, the study by Ke and Lee (2016) only had two participants with HFA, whereas Cheng et al. (2015) study only had three samples; in comparison, the largest participants number is 47 by Serret et al. (2014). Only two out of the six studies compared HFA to the control, as evidenced by a study by Ke and Lee (2016), which used a typically developing peer and in Zhao et al. (2022), the controlled group was only exposed to conventional face-to-face rehabilitation training. Moreover, only the study by Junqiang et al. directly compared VR interventions to the conventional approach, and the rest of the studies only measured the effectiveness of the VR intervention. Lastly, all the studies have different types of intervention and different outcome measures, making it difficult to conclude the outcome of this review.

Despite the promising results of VR use in skills training, as evidenced in the literature, there is concern about the 'uncanny valley' effect. The uncanny valley is generally defined as the shift of people's response to a human-like artefact from high affinity to aversion when the artefact approaches but fails to attain an actual human appearance (Kaba 2013; Schindler et al. 2017). Studies strongly suggested that the effect was caused by the mismatched elements that created the creepiness feeling (McAndrew & Koehnke 2016; Mitchell et al. 2011). Interestingly, individuals with ASD responded differently, as demonstrated by Ueyama in 2015, a Bayesian model of the uncanny valley effect in patients with ASD appears like a cliff rather than a valley. Another study proved that children with ASD have an absence of the uncanny valley effect, which might be attributed to their reduced sensitivity to subtle changes of facial features caused by diminished social motivation (Feng et al. 2018). However, a few steps can be taken to reduce the uncanny valley effects. For example, by avoiding the high level of human-likeness and by avoiding similarities by using childish features for stylisation, like in the movie, The Incredibles (Bird 2004), in which the characters

were designed to be more cartoon-like so people will not get confuse between real-live or animation (Kaba 2013; Schwind & Wolf 2018).

Notwithstanding the advancement in knowledge of illness and pharmaceutical technology, the mainstay of management in patients with ASD remains non-pharmacological approaches. As discussed earlier, patients with ASD endure deficits in many crucial skills, such as communication and social skills. Granted, the multidisciplinary approach has been widely adopted to ensure comprehensive and holistic care for the patients; however, with the staggering increase in the number of patients with ASD, the healthcare sector-including psychiatrists, clinical psychologists and occupational therapists-is struggling to deliver quality necessary skills training while trying to make best with their limited human resources and inadequate training (Dillenburger et al. 2016; McConkey & Bhlirgri 2003). Due to the limited number, more training should be done for the staff so that they can handle patients with ASD better (Gerhardt & Lainer 2011; McDonnell et al. 2008).

In light of this, the introduction of VR for social skills training comes at an opportune moment. It has the potential to be a valuable addition to the existing armamentarium in managing such patients. VR has the unique advantage of enabling patients to practice social skills in a non-threatening, synthetic but realistic, motivating, controllable and diversifiable environment (Bellani et al. 2011; Ke et al. 2022). As demonstrated in previous studies, owing to its interactive and engaging nature, the elements of gamification in VR could also have benefits in improving engagement, attendance and participation (Constain et al. 2019; Dicheva et al. 2015; Ramos Aguiar et al. 2023). All of these are important factors which may influence the effectiveness of learning such skills, and their impact should not be understated.

On the other hand, one potential opportunity that is attracting more attention nowadays is the possibility of conducting therapy and skills training at their own home. While the concept of therapy at home, occasionally by the visiting occupational therapist, is not exactly new, the shortage of therapists in the first place (Kadar et al. 2015), compounded by the prohibitively expensive charges, render it an unsustainable choice for long-term treatment (Little et al. 2018). In reality, to ensure the retention of the skills learned, it is not sufficient to put the responsibilities on the therapist alone in those limited sessions; rather, it takes continuous practice to ensure mastery of the skills. Therefore, VR might be one of the possible solutions for bringing the therapy sessions back home. One better example of this is Floreo, a learning app that uses VR as a method for teaching science-based social and communication skills to individuals with ASD (Ravindran et al. 2019). Most of the parents were enthusiastic about the concept of Floreo, simplifying the process for parents by allowing them to help their child at home rather than preserving the need to travel to a therapist's office or some other location for valuable services. It also allows parents to see what their child is seeing so they can provide feedback and customisation. This opens up numerous interesting and exciting opportunities for more meaningful treatment in the neurodivergent population.

As demonstrated in this systematic review, most of the studies exploring VR application in social skills training in high-functioning autism populations were conducted in countries with a more advanced economy, such as the United States, the United Kingdom and Taiwan. Whilst the advancement in research is appreciated

and enhanced the understanding, further exploration is needed to study the practicality of its implementation in low- and middle-income countries (LMIC). The rates of ASD and other disabilities have increased significantly in sub-Saharan Africa and Southeast Asia over the last few decades (Olusanya et al. 2018), which further exacerbates the existing challenges of accessing appropriate services and treatments (de Vries 2016). VR can offer some solutions to narrow the gap and improve access to necessary skills training. However, in a pragmatic sense, there is more than meets the eye-one study highlighted the importance of assessing fundamental principles of affordability, accessibility, acceptability and cultural appropriateness in determining the feasibility of the use of such technologies in LMIC (Kumm et al. 2022). Hence, careful consideration by the relevant stakeholders shall be a priority to ensure the effectiveness and sustainability of the initiative and not just another white elephant project in an already resource-stricken region.

Moving forward, more studies should be focused on younger age groups to allow incorporation as a part of early intervention. Furthermore, the usage of VR as a medium for social skills training should be extended across the autism spectrum, not only focusing on HFA. Lastly, more RCT is needed to establish the effectiveness of VR platforms in improving social skills.

CONCLUSION

This systematic review highlights the potential of VR interventions for enhancing social skills in individuals with HFA. However, further research with rigorous designs and standardised outcome measures is needed to establish the efficacy and optimal implementation of VR interventions for social skill training in individuals with HFA. These findings have important implications for the development of innovative and personalised interventions to improve the social functioning and quality of life of individuals with ASD.

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