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*Review*

# Virtual Reality as a Mediating Tool in Addressing Social Communication Disorder: Current Understanding and Implementation Strategies

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**Abstract**

Social Communication Disorder (SCD) involves persistent verbal and non-verbal communication difficulties, significantly impacting children and adolescents' social interactions. Traditional interventions, while valuable, face practical limitations, including difficulties replicating real-world social contexts and low engagement among some learners. This paper examines Virtual Reality (VR) as an innovative intervention tool for SCD through a comprehensive review of empirical studies (2010–2024). Analysis of 11 peer-reviewed studies, encompassing both autism spectrum disorder (ASD)-specific and broader SCD populations, revealed five key themes being discussed in the current literature: usability and acceptability, social skills training, gaze and attention tracking, measurement and assessment, and applications in inclusive education. Our findings demonstrate VR's potential as a mediating tool between therapeutic interventions and real-world social interactions, offering controlled yet naturalistic environments that enable safe, structured practice while maintaining engagement. The alignment with cognitive science principles enhances learning processes through effective management of cognitive demands. Building on these findings, we propose implementation strategies for educational and therapeutic settings, addressing design considerations, delivery methods, and outcome evaluation. This synthesis advances the understanding of VR as an innovative, scalable approach to supporting social communication development in children and adolescents.

**Keywords:** social communication disorder; virtual reality; immersive learning environments; therapeutic technology



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## 1. Introduction

Social Communication Disorder (SCD) is a neurodevelopmental condition characterised by persistent difficulties in the social use of verbal and non-verbal communication (Topal et al., 2018). Individuals with SCD struggle to engage effectively in social interactions, often finding it challenging to understand conversational rules such as turn-taking, the use of non-literal languages like idioms and metaphors, and interpreting non-verbal cues, including facial expressions, gestures, and eye contact (Hage et al., 2021). These challenges can lead to significant social disadvantages during the critical developmental stages of childhood and adolescence. Children and adolescents with SCD often face challenges in communicating effectively with their peers, hindering their ability to form and maintain meaningful relationships and collaborate in school settings (Eadie et al., 2018). These difficulties increase their vulnerability to peer rejection, bullying, and social

isolation, all of which can contribute to a higher risk of school dropout (Nordin et al., 2024). Research consistently found that individuals with SCD are at greater risk for poor academic achievement, the development of mental health disorders such as depression and anxiety, and suicide (Saul et al., 2023). Although traditional approaches such as speech-language therapy and social skills training have been widely adopted to address these challenges, they often encounter practical limitations (Logan et al., 2017). These include difficulties replicating real-world social contexts, a lack of opportunities for repeated practice in controlled environments, and low levels of engagement among some children and adolescents. These constraints highlight the urgent need for innovative approaches to SCD intervention that address these gaps in accessibility, personalisation, and generalisability.

Virtual Reality (VR) in education provides immersive, interactive, and engaging learning experiences that foster personalised learning, enhance understanding through 3D simulations, and address key challenges such as supporting students with special needs and enabling remote access to education (Javaid et al., 2024). The last decade has seen VR emerge as a promising technological tool for treating and rehabilitating social communication disorders. By creating immersive, computer-generated environments, for example, VR provides a safe and controlled platform for individuals to simulate real-world experiences (Alimanova et al., 2022). Unlike traditional interventions, VR enables learners to practise social interactions without the stress or unpredictability of actual social encounters, making it particularly beneficial for children who find such experiences overwhelming (Vairamani et al., 2024). Recent advancements in VR technology have also allowed for the development of systems that can be tailored to meet individual needs, offering highly personalised interventions that address specific communication deficits (Arts et al., 2024). VR also facilitates repeated practice, an essential component of learning, while providing immediate feedback to support skill acquisition (Kolk et al., 2023). Furthermore, the interactive and multisensory nature of VR, combining visual, auditory, and experiential inputs, enhances engagement and motivation, particularly for children with neurodevelopmental challenges who benefit from visual and hands-on learning approaches (Bekele et al., 2016; Kolk et al., 2023).

In recent years, VR-based interventions have demonstrated significant potential for improving social communication skills in children and adolescents. For instance, studies have shown that VR can enhance collaboration, emotion recognition, and problem-solving abilities, particularly among children with Autism Spectrum Disorder (ASD) (Ke et al., 2022). Collaborative Virtual Environments (CVEs) have been successfully used to encourage peer-based social interactions, while adaptive VR systems integrating gaze tracking and physiological monitoring have enabled the development of personalised feedback mechanisms that target gaze behaviour and emotion recognition (Lahiri et al., 2011; Zhao et al., 2018). Although VR research has primarily focused on children with ASD, emerging evidence indicates that its applications may extend to broader SCD populations, including those with developmental language disorders (DLD) and neurological conditions (Arts et al., 2024; Kolk et al., 2023). Notably, Ip et al. (2018) reported significant improvements in emotional expression and social reciprocity for children with ASD following participation in an immersive VR-enabled intervention, while Cheng et al. (2015) demonstrated the feasibility of a 3D immersive virtual environment to enhance non-verbal communication and social understanding in a single-subject design ($N$ = 3). Both studies contribute to the growing body of evidence supporting VR-based interventions for ASD. Despite these promising findings, the full potential of VR in addressing SCD remains underexplored. Current research lacks consensus on long-term effectiveness, generalisation of skills to real-world contexts, and the practical implementation of VR interventions in educational and clinical settings.

This paper aims to address these gaps by providing a critical discussion of the role of VR in the treatment and rehabilitation of SCD. We included both ASD-specific and non-ASD-specific studies in order to capture the breadth of research on VR as a tool for supporting social communication difficulties. ASD-related studies were included where they addressed mechanisms or outcomes that could inform broader SCD populations. However, studies focusing exclusively on ASD without consideration of their broader implications (e.g., Ip et al., 2018; Cheng et al., 2015) were excluded from the final synthesis, though we discuss their relevance in framing the field. It also examines the theoretical underpinnings that make VR particularly suited to addressing the challenges associated with SCD. Building on this foundation, the discussion explores strategies for implementing VR-based interventions in educational and therapeutic settings, with particular attention to design considerations, delivery methods, and outcome evaluation. By synthesising current evidence and proposing practical strategies, this paper seeks to advance the understanding of VR as an innovative, scalable, and effective approach to supporting social communication development in neurodiverse children and adolescents. This discussion is particularly timely as educational systems increasingly adopt immersive technologies to enhance accessibility and personalisation. The paper also sets the stage for the broader contributions in this special issue of Languages, which collectively explore the potential of virtual and augmented reality in transforming language learning, communication, and inclusion across diverse populations.

## 2. Methods

A comprehensive literature review was conducted following a structured search protocol to identify relevant peer-reviewed studies examining VR applications in addressing SCD among children and adolescents. Given the interdisciplinary nature of this research area, which spans technology, education, psychology, and clinical domains, we conducted searches across PubMed, Scopus, ERIC, CINAHL, and PsycINFO databases to ensure thorough coverage.

The search strategy focused on three intersecting concepts: virtual reality technology, social communication disorders, and developmental populations. The final search string combined relevant keywords using Boolean operators: ("Virtual Reality" OR "VR" OR "immersive technology") AND ("social communication disorder" OR "social communication deficit" OR "speech-language therapy" OR "social skills training") AND ("children" OR "adolescents" OR "youth"). Additional search refinements included synonyms and related terms specific to each database's controlled vocabulary.

The inclusion criteria for this review required studies to target children with SCD, broadly defined to include but not be limited to ASD, and to employ group-based or experimental designs with sufficient sample size for thematic analysis. Studies focusing exclusively on ASD or utilising single-subject designs, such as Ip et al. (2018) and Cheng et al. (2015), were reviewed and cited for context, but were not included in the final synthesis to maintain methodological consistency and relevance across diverse populations.

The date range of 2010–2024 was chosen to capture contemporary developments in VR technology while maintaining relevance to current educational and therapeutic practices. Articles were considered for inclusion based on several criteria: (1) peer-reviewed empirical research published in English, (2) focused on VR-based interventions or assessment tools, and (3) targeting child or adolescent populations with SCD, including those with and without ASD.

The search initially identified 489 records. After removing duplicates, 432 titles and abstracts were screened independently by two reviewers. Of these, 45 articles were retained for full-text review. Studies were excluded if they were not empirical, did not focus on

VR-based interventions, did not target social communication outcomes, or were centred on adult populations. Ultimately, 11 studies met all inclusion criteria and were included in the review. Disagreements during the screening process were resolved through discussion between reviewers. Consistent with established scoping review methodologies, our focus was on mapping the range and nature of current research, with inclusion criteria carefully calibrated to ensure methodological and conceptual relevance. We acknowledge that scoping reviews typically conduct a bias appraisal of the sources included in a scoping review, but not a quality appraisal (Peters et al., 2021), and "critical appraisal of the sources of evidence included in scoping reviews is generally omitted, [however], the reviews themselves may still need to be assessed for bias if they are to be used for decision-making or to inform future research directions" (Pollock et al., 2022). Therefore, rather than employing a formal quality appraisal tool such as the MMAT, we applied rigorous thematic alignment criteria, thereby ensuring that the synthesis is grounded in the most pertinent and actionable evidence available. This approach is particularly effective when examining innovative and interdisciplinary interventions, where the field's rapid evolution is best captured by targeted, concept-driven synthesis. The review process is summarised in Figure A1, following PRISMA 2020 guidelines (Page et al., 2021a, 2021b).

Of all the 11 studies that met all inclusion criteria and quality standards, four investigated VR applications in general SCD populations, while seven focused specifically on children with ASD. The relatively small number of included studies reflects both the emerging nature of VR technology in this field and the stringent inclusion criteria applied to ensure high-quality evidence. While this focused approach ensures thematic alignment, we acknowledge that the small number of included studies (n = 11) potentially limits the generalisability and reliability of our synthesis. The restricted evidence base means that the themes identified should be viewed as indicative rather than exhaustive, and further research may yield additional or differing insights as the field evolves.

Our use of a scoping review approach enabled a comprehensive mapping of the breadth and diversity of research activity in this rapidly developing area. This methodology is well-suited to emerging fields characterised by heterogeneous designs and evolving intervention models. However, it is important to note that the broad scope and inclusion of diverse study types may limit the specificity and depth of conclusions regarding intervention effectiveness. As the evidence base expands, complementary systematic reviews and meta-analyses will be critical for synthesising high-quality, comparative data and informing best practice.

## 3. Findings and Discussion

Our analysis of the included studies yielded five interrelated themes that collectively capture the current state of VR research in supporting social communication. Theme 1 addresses usability and acceptability, and highlights the importance of user engagement, system adaptability, and stakeholder perceptions in determining the successful integration of VR interventions. Theme 2 examines the role of VR in social skills training and social interaction among autistic children, further underscoring both the promise of immersive scenarios and the relevance of ASD-focused research. Theme 3 considers the integration of gaze and attention tracking and demonstrates how VR systems can provide real-time, adaptive feedback to target atypical social attention patterns. Theme 4 focuses on VR as a measurement and assessment tool, therefore, emphasising its potential for scalable, objective, and ecologically valid evaluation of social communication outcomes. Finally, Theme 5 explores applications of VR for broader SCD populations in inclusive education, which shows how immersive environments support socio-emotional development and communication across diverse neurodevelopmental conditions. Together, these themes

highlight the multifaceted potential of VR as both an intervention and an assessment tool for social communication difficulties, while also pointing to gaps in generalisability, particularly beyond ASD-specific contexts.

These themes are documented in Appendix A, which maps the literature according to its primary focus and population studied. Together, they provide insights into VR's potential as an innovative intervention approach, while also highlighting considerations for implementation in educational and therapeutic settings. Table A1 summarises the key findings and themes.

To derive the five themes, we employed a systematic and iterative thematic synthesis approach (see Morgan & Nica, 2020), following established guidance for qualitative evidence synthesis (Gottlieb et al., 2021; Marshall, 2019; Thomas & Harden, 2008). First, two reviewers independently read all included studies in full and extracted key findings relevant to VR interventions for social communication disorder. Following reading of the extracted texts for familiarisation, text coding occurred by labelling each relevant segment of text (e.g., intervention features, outcome measures, participant experiences) to capture salient concepts across studies. The initial codes were then discussed and compared, with similar codes grouped into preliminary categories. Through further iterative discussion and constant comparison, these categories were refined and consolidated into broader candidate themes. Disagreements were resolved by consensus, and the generated themes were tested against the data to ensure that each theme was clearly supported by multiple studies and captured an important aspect of the literature. Finally, the definitions and boundaries of each theme were reviewed, clarified, and, where necessary, adjusted to enhance internal coherence and distinctiveness. This process resulted in the identification of five overarching themes, each representing a key dimension of VR-based intervention research for social communication disorder.

Theme 1: Usability and acceptability of VR in social communication interventions. The usability and acceptance of VR are critical for its successful integration into educational and therapeutic contexts. Vaezipour et al. (2022) examined clinician perceptions of immersive VR for communication rehabilitation. Using a mixed-methods approach, they found that speech-language pathologists viewed VR as a valuable tool for simulating real-world communication scenarios. However, the study identified several barriers, including limited clinician familiarity with VR technology, resource constraints, and challenges in integrating VR into existing workflows. In a study involving children with ASD, Gayle et al. (2024) reported high levels of usability and acceptance of VR equipment and software. All participants readily accepted VR after minimal acclimatisation, and the sessions were positively received by both children and their caregivers. The study also highlighted indices of happiness, demonstrating that VR can create a motivating and enjoyable experience for children. These findings underscore the importance of user engagement and system adaptability when developing VR-based interventions, particularly for neurodiverse populations.

Theme 2: VR for social skills training and social interaction in ASD. VR has shown considerable promise as a platform for social skills training, particularly in autistic children. Zhao et al. (2018) developed a CVE system to foster peer-based communication in children with ASD. In the feasibility study, participants demonstrated improved cooperation and verbal interactions during collaborative gameplay. The study's design, which incorporated gaze-based communication and hand gestures, highlights VR's capacity to encourage naturalistic social interactions while providing a safe and controlled space for practice. Similarly, Ke et al. (2022) explored VR-based social skills training through role-play, gaming, and collaborative design tasks. Their findings showed significant improvements in social communication, including enhanced cooperation and turn-taking skills. The authors attributed these outcomes to VR's ability to provide immersive, goal-directed scenarios that

naturally motivate children to engage. Alimanova et al. (2022) added an innovative layer to VR interventions by integrating artificial intelligence (AI) to adapt the behaviour of virtual characters based on user actions and emotional cues. This system provided personalised training opportunities and facilitated repetitive practice in a realistic environment. These studies collectively illustrate VR's utility in promoting social engagement, peer collaboration, and communication skills among children with ASD. Overall, the prominence of ASD-focused studies in the literature is reflected in this theme. While these studies provide important insights into the potential of VR for social skills training, their findings may not be fully generalisable to children with other forms of SCD. This underscores the need for further comparative research across different diagnostic groups.

Theme 3: Gaze and attention tracking in VR for social communication. Gaze behaviour is a critical component of social communication, and VR systems incorporating gaze tracking have shown promise in addressing attention deficits in children with SCD. Lahiri et al. (2011) developed a VR-based system that combined eye-tracking technology with adaptive response features. Their findings indicated that real-time feedback effectively modified gaze patterns, encouraging participants to focus on socially relevant cues, such as facial expressions. This targeted approach aligns with the need to address atypical eye-gaze behaviours often observed in children with ASD. Bekele et al. (2016) extended this concept by integrating physiological sensors, such as EEG and biosensors, into a VR platform. Their study demonstrated the feasibility of using multimodal feedback to adapt interventions based on participants' engagement and emotional responses. The real-time measurement of gaze and physiological signals allowed for a personalised intervention, highlighting VR's ability to dynamically respond to individual needs.

Theme 4: Measurement and assessment of social communication skills in VR. VR systems have also been explored as tools for assessing social communication and collaboration. L. Zhang et al. (2020) introduced an intelligent CVE platform (CRETA) designed to autonomously measure communication and collaboration in children with ASD. By using AI to classify user statements and interactions, the system demonstrated moderate to high accuracy compared to human assessments. These findings suggest that VR systems can provide scalable, objective methods for measuring social communication skills, which may reduce the reliance on time-intensive observational coding and subjective reporting. Vaezipour et al. (2022) similarly highlighted the role of VR as an assessment tool, emphasising its capacity to simulate realistic scenarios for evaluating communication outcomes. These studies position VR as a valuable tool for both intervention and objective assessment, offering the potential for more consistent and reliable evaluation of social communication progress.

Theme 5: VR for SCD in inclusive education. Although much of the literature focuses on children with ASD, several studies have explored VR's application to broader SCD populations. Vairamani et al. (2024) reviewed the potential of VR to improve social communication skills in children with broad special needs in inclusive education. The authors highlighted VR's capacity to create immersive, engaging environments where children could practise social scenarios repeatedly and safely. Arts et al. (2024) investigated VR interventions for adolescents with DLD, demonstrating improvements in socio-emotional functioning. The study emphasised the importance of VR as a non-verbal, accessible medium for children who experience significant language-based challenges. Kolk et al. (2023) introduced a hybrid intervention combining multitouch technology with VR to train social communication skills in children with neurological conditions. Their findings revealed improvements in empathy, cooperation, and theory of mind, underscoring VR's broad applicability in addressing communication deficits across diverse populations. This also raises opportunities to extend VR interventions to culturally and linguistically diverse

learners, whose first languages may present distinctive morpho-syntactic structures (e.g., Abeillé et al., 2020; Furukawa & Nakamura, 2024; Han, 2013; Han & Shi, 2016) and who may benefit from non-verbal, immersive platforms that reduce linguistic barriers and provide repeated practice in socially meaningful contexts (e.g., Alfadil, 2024; Han et al., 2016; Zhi & Wu, 2023).

Overall, the themes identified from the reviewed literature highlight the potential of VR as a tool for addressing core social communication deficits in children and adolescents with SCD. One of the most compelling arguments for VR lies in its capacity to replicate naturalistic social experiences while maintaining a high degree of control over environmental variables, thereby allowing learners to engage in *safe* and *structured* practice (Zhao et al., 2018). This level of control is particularly beneficial for individuals with SCD who often experience anxiety or sensory overload in real-world social contexts. In contrast to conventional interventions such as role-playing in a clinic or classroom, VR interventions can systematically manipulate visual and auditory stimuli to meet individual needs, offering graded exposures that gradually build confidence and competence in social interactions (Alimanova et al., 2022).

A consistent finding in the literature is that VR-based interventions support both verbal and non-verbal communication goals. Because SCD often entails difficulties with pragmatic language use and understanding of social cues (Hage et al., 2021), strategies that harness immersive simulations are especially pertinent. For instance, VR platforms can incorporate realistic avatars and facial expressions, enabling learners to practise interpreting and responding to non-verbal signals, including gestures and body language, in a controlled setting (Lahiri et al., 2011). Additionally, VR systems equipped with gaze tracking and real-time feedback mechanisms have demonstrated success in reshaping attentional patterns, nudging children to notice important social cues, such as a conversation partner's gaze or change in effect, thus bolstering skills closely tied to embodied cognition and social reciprocity (Bekele et al., 2016; Lahiri et al., 2011).

Another distinctive feature of the VR approach is its ability to *personalise* learning experiences. Children with SCD, including those with ASD, often present with heterogeneous communication profiles, ranging from mild to more pronounced difficulties in areas such as turn-taking, topic maintenance, and emotion recognition (Ke et al., 2022). In this context, VR interventions can adapt in real time to match each learner's current level of functioning, gradually introducing more complex language demands or more nuanced facial expressions as proficiency grows (L. Zhang et al., 2020). The capacity for tailoring interventions is further enhanced by the use of AI within VR platforms, enabling them to adjust the behaviour of virtual agents according to the user's performance and engagement (Alimanova et al., 2022). These adaptive features align well with modern pedagogical and therapeutic principles that call for *individualised* and *responsive* instruction. It is important to acknowledge that ASD-related research constitutes a substantial portion of the evidence base. While this provides valuable insights into how VR may support social communication, the reliance on ASD-specific studies creates challenges for generalising findings to populations with developmental language disorders, neurological conditions, or other forms of SCD. For example, while interventions for ASD often target social reciprocity and perspective-taking (Bohlander et al., 2012; Dawson & Burner, 2011; Tierney et al., 2014), children with other communication disorders may require different emphases. This heterogeneity highlights the importance of broadening the evidence base beyond ASD-focused populations.

The predominance of studies focusing on children with ASD within the current evidence base reflects both the prevalence of research in this area and the centrality of social communication challenges in ASD. However, this focus introduces important consider-

ations regarding generalisability. While children with ASD and those with other forms of SCD (such as DLD or neurological conditions) often share pragmatic communication difficulties, the underlying cognitive, linguistic, and neurobiological mechanisms, as well as their associated intervention needs, can differ substantially. For example, children with DLD may experience greater challenges related to linguistic processing and vocabulary, while those with neurological conditions may have unique profiles of social cognition and executive function. As a result, the transferability of intervention strategies and outcomes from ASD-specific studies to other SCD populations should be considered with caution. The themes and recommendations identified in this review are therefore most robustly supported for ASD populations but also offer valuable starting points for future adaptation and validation in other groups. Explicit research targeting these distinct populations remains a priority for the field.

Furthermore, high levels of *motivation* and *engagement* further distinguish VR from more traditional interventions. Multiple studies have reported that children find VR-based tasks intrinsically rewarding, which can reduce resistance to therapy and increase their willingness to practise essential skills repeatedly (Gayle et al., 2024; Ke et al., 2022). This heightened engagement is critical given that social communication skills often require extensive, consistent practice to achieve generalisation beyond the treatment setting. By leveraging game elements and visually appealing interfaces, VR can transform repetitive drills, such as practising conversational initiations or reading facial expressions, into interactive, goal-directed tasks, effectively sustaining attention and encouraging incremental progress (Arts et al., 2024).

From the cognitive perspective, VR interventions for SCD align with key tenets of the Cognitive Load Theory (Paas et al., 2004; Sweller, 1988) and the Dual-Channel Theory (Mayer, 2009). In traditional therapy contexts, learners with SCD may face excessive extraneous load due to unpredictable social cues or environmental distractions. The reviewed studies demonstrate how VR addresses this challenge through controlled environments. For instance, systems incorporating gaze tracking and adaptive feedback (Bekele et al., 2016; Lahiri et al., 2011) can eliminate unpredictable elements while maintaining meaningful social interaction opportunities. By offering an immersive but highly controlled environment where social tasks can be scaffolded, VR effectively reduces both intrinsic and extraneous cognitive loads.

Dual-Channel Theory (Mayer, 2009) provides crucial insight into VR's effectiveness by highlighting how humans process auditory and visual information separately, with each channel having limited capacity. VR leverages this principle by distributing social cues (e.g., facial expressions, tone of voice) across both channels in a structured way, as demonstrated in studies utilising multimodal feedback systems (Bekele et al., 2016). This structured distribution helps learners devote cognitive resources more efficiently to crucial communication tasks. The integration of physiological monitoring with VR feedback has been shown in recent studies (Alimanova et al., 2022), further illustrating how these platforms can optimise the presentation of social information across different processing channels.

Cognitive Load Theory (Sweller, 1988) and Dual-Channel Theory (Mayer, 2009) are frequently cited to explain the potential of VR environments to facilitate learning by providing immersive, multimodal experiences. In principle, VR-based interventions may optimise cognitive processing by leveraging both visual and auditory channels, supporting the integration and retention of social communication skills. However, it is important to note that none of the studies included in this review directly measured cognitive load or examined dual-channel processing outcomes. As such, while these theories offer useful frameworks for interpreting the design and hypothesised benefits of VR interventions,

further empirical research is required to substantiate claims regarding their impact on cognitive processing and learning in this population.

Furthermore, the immediacy of feedback and the capability to gradually increase scenario complexity are features highlighted across multiple studies (L. Zhang et al., 2020; Zhao et al., 2018), allowing individuals with SCD to practice interpreting non-verbal signals, sustaining attention, and engaging in turn-taking without becoming overwhelmed. This careful calibration of task difficulty aligns with cognitive load principles while maintaining engagement. In this manner, VR-based interventions strategically manage cognitive load, facilitating deeper learning and more robust transfer of social communication skills to real-world interactions (Mayer, 2009; Sweller, 1988).

Collectively, these thematic insights affirm the evolving role of virtual reality as both an intervention and assessment modality for social communication challenges. The studies reviewed not only highlight VR's unique affordances (i.e., immersiveness, adaptability, and engagement) but also raise critical questions about implementation fidelity, ethical design, and long-term efficacy. The contributions in this special issue extend this conversation by exploring diverse learner populations, pedagogical approaches, and multimodal applications of VR in language learning and communication contexts.

The five key themes identified in this review provide a comprehensive overview of the current evidence for VR-based interventions in social communication disorder. Each theme captures a distinct aspect of intervention development, implementation, or evaluation. By synthesising findings across studies, our review highlights not only areas of emerging consensus but also ongoing methodological and conceptual challenges. In the following discussion, we relate each theme to established theoretical perspectives and outline implications for research and practice. By synthesising the current evidence across multiple domains, our review delivers a timely and integrated understanding of VR's application in social communication disorders. The focused sample and inclusive methodological approach provide unique insight into both established findings and future research priorities. This perspective is especially valuable at a stage when technology, practice, and evidence are advancing rapidly. As the field develops, ongoing work that builds on this foundation, expanding sample sizes and integrating formal quality assessment, will further strengthen the reliability and impact of research in this area.

## 4. Implications for Practice

The findings from this review collectively demonstrate VR's distinct capabilities in addressing core challenges in social communication intervention. The technology's ability to create controlled yet naturalistic environments addresses the fundamental challenge of providing safe practice opportunities, while its capacity for personalisation through adaptive systems responds to the heterogeneous nature of social communication needs. Providing a safe environment for practising social skills through VR could be especially beneficial for vulnerable children and adolescents with SCD, particularly those with a history of trauma (e.g., bullying) and those who exhibit high levels of social anxiety in real-world interactions. The documented high levels of engagement across studies suggest VR can sustain the consistent practice necessary for skill development. Furthermore, the theoretical grounding in cognitive science principles provides insight into why these technological affordances may be particularly effective for social communication learning.

These complementary aspects position VR as a promising mediating tool between therapeutic intervention and real-world social interaction. Rather than replacing traditional approaches, VR offers a structured bridge where learners can develop social communication skills through carefully calibrated experiences. The evidence suggests this mediation role is particularly valuable for supporting the gradual transition from controlled practice

to naturalistic social situations, a progression that has traditionally been challenging to facilitate in social communication intervention.

Practically, the effective implementation of VR in this mediating role requires careful consideration of several key dimensions.

*Integration with Existing Practice.* This implication builds on Themes 2 and 3. Theme 2 emphasised the importance of designing VR interventions that are engaging, developmentally appropriate, and responsive to the needs of diverse users. Evidence from the reviewed studies highlighted how user engagement is influenced by scenario realism, interactivity, and personalisation. Theme 3 highlighted the importance of aligning VR-based interventions with established clinical routines and interdisciplinary collaboration. The studies reviewed consistently emphasised the need for practical integration strategies to maximise uptake and sustainability. The implementation of VR interventions requires careful consideration of how they complement existing therapeutic approaches. Vaezipour et al. (2022) identified specific challenges in integrating VR into existing clinical workflows, highlighting the need for clear implementation protocols. Practitioners need well-defined frameworks for incorporating VR-based activities into their intervention programs, particularly regarding the timing and progression of virtual experiences. This includes developing evidence-based criteria for matching VR activities to individual learning needs and abilities of children and adolescents with SCD, establishing clear protocols for session structure and duration, and creating systematic pathways for transitioning between virtual and real-world practice. The integration process should also consider how VR activities can reinforce goals being addressed in traditional therapy sessions, ensuring a coordinated approach to social communication development.

*Design Considerations.* The importance of careful design was underscored by Theme 1, where user-centred and context-specific design features were identified as critical for engagement and effectiveness. Evidence from the review points to the need for customisation, accessibility, and iterative testing in developing VR content. SCD encompasses a broad range of communication profiles and severity levels. Effective VR interventions should therefore incorporate *personalisation* and *adaptive* capabilities to align with each learner's unique challenges and progress. For instance, difficulty levels can be dynamically adjusted based on a user's performance data, e.g., gaze-tracking metrics or frequency of successful social interactions, ensuring that tasks remain appropriately challenging without causing frustration or disengagement. Automated feedback loops, powered by AI or pre-programmed decision trees, can further refine the intervention to match evolving skill levels.

Immersive VR platforms leverage visual, auditory, and sometimes tactile modalities to support the development of social communication skills (Bekele et al., 2016). Real-time feedback, whether via on-screen prompts, avatar facial expression changes, or audio cues, can help children with SCD quickly correct misinterpretations of social signals (Lahiri et al., 2011). The design should take full advantage of VR's multimodal capabilities while carefully managing cognitive load.

Children are more likely to persist with VR-based social skills training when tasks are intrinsically motivating (Gayle et al., 2024; Ke et al., 2022). Incorporating game-like elements, such as progression levels, scores, or rewards, can sustain engagement over repeated sessions, a critical factor for generalising skills to real-world contexts. However, gamification should be employed judiciously to not distract from therapeutic objectives; the central focus must remain on improving social communication skills rather than merely 'gaming' within the virtual environment.

Beyond ensuring engagement, it is also important to consider how incorporating VR can facilitate the transfer of skills to everyday settings (L. Zhang et al., 2020). Incorporat-

ing scenarios that closely resemble children's typical environments, such as classrooms, playgrounds, or home-like settings, can enhance ecological validity. Additionally, explicit *debriefing sessions* or built-in reflection prompts within the VR experience can help learners connect virtual practice to real-world applications, thereby reinforcing newly acquired skills.

*Delivery Methods*. Findings synthesised in Theme 4 revealed variability in delivery models, including individual versus group formats, and the impact of setting (school, clinic, home) on intervention outcomes. These observations inform our recommendations regarding optimal delivery methods. Three broad approaches: clinic-based, school-based, and home-based implementations, have emerged as viable methods for VR intervention delivery (Kouijzer et al., 2023; F. Zhang et al., 2024).

In clinical settings, speech-language pathologists, psychologists, or other professionals can incorporate VR sessions as part of a broader therapy plan. This model benefits from the immediate availability of expert supervision, facilitating timely feedback and adjustments to the intervention. Logistical constraints, such as families' travel time and clinicians' workloads, may limit session frequency.

Meanwhile, schools provide a natural environment for repeated practice and peer interaction, both of which are integral to improving social communication. Embedding VR activities into existing classroom routines may enhance ecological validity, permitting learners to rehearse adaptive social behaviours alongside familiar peers. Successful school-based adoption often hinges on teacher training and the availability of adequate resources, factors that can significantly influence the fidelity of implementation.

VR interventions for children and adolescents with SCD could be a valuable complement to existing school-based interventions, such as social skills training programs. These programs are typically delivered in person to large groups or entire classrooms, which can make it difficult for children and adolescents with SCD, particularly those with social anxiety, to fully engage with and benefit from (Durlak et al., 2022). In contrast, VR interventions offer a more personalised experience within a safe, controlled environment. This can enable these individuals to engage more effectively and develop social skills at their own pace, providing a more tailored and effective approach to supporting their social development.

Although less common in the literature, remote or home-based VR sessions offer the promise of extended practice opportunities and reduced scheduling barriers. When paired with teleconsultation, parents or caregivers can receive real-time guidance from clinicians, thereby maintaining a degree of professional oversight. However, families' comfort with technology, along with varied home environments and potential inconsistencies in device availability, can introduce variability in outcomes.

*Outcome Evaluation.* As discussed in Theme 5, robust and standardised outcome measurement remains a major challenge in the field. The lack of consistent longitudinal data and reliance on immediate post-intervention assessments directly inform our call for improved evaluation strategies. The implementation of VR interventions necessitates robust approaches to measuring and evaluating outcomes. A review of outcome evaluation approaches across the included studies reveals a reliance on immediate post-intervention measures, often assessed within highly controlled or laboratory-based settings. Standardised assessment tools, such as established pragmatic language scales or social skills inventories, are used inconsistently, with several studies instead employing bespoke task performance metrics or qualitative observations tailored to the specific VR intervention. This variability in measurement not only complicates cross-study comparison but also highlights the need for consensus on core outcome sets and the systematic use of validated instruments.

More importantly, the evidence base remains limited in demonstrating the durability and generalisation of acquired skills. Few studies include follow-up data or systematically assess the transfer of social communication improvements to naturalistic, real-world settings such as classrooms or peer interactions. This represents a significant gap, as the clinical effectiveness of VR interventions ultimately depends on the sustained application of skills beyond the training environment. Addressing this limitation will require future research to adopt longitudinal designs, incorporate standardised and ecologically valid outcome measures, and directly examine the factors that promote or hinder generalisation.

Educational and therapeutic settings, therefore, should develop comprehensive assessment frameworks that track progress across both virtual and real-world contexts. These frameworks should include clear metrics for measuring social communication development. Evaluation protocols should specifically address skill transfer between virtual and natural environments. This involves developing methods for assessing how effectively learners apply skills practised in VR to real-world social situations. Settings should establish clear criteria for determining when learners are ready to advance to more challenging virtual scenarios and when they demonstrate sufficient skill mastery for reducing VR support. The evaluation framework should also include methods for gathering feedback from learners, families, and practitioners to ensure the intervention effectively meets therapeutic objectives while maintaining engagement.

Overall, these implications underscore VR's transformative potential as a mediating tool between therapeutic intervention and real-world social communication. By aligning design, delivery, and evaluation principles with cognitive and developmental insights, practitioners can harness VR to support more inclusive, engaging, and effective communication development. As educational and clinical environments move toward blended and technology-enhanced approaches, it becomes critical to consider the professional training, infrastructure, and equity factors required to sustain such innovations. This special issue aims to further extend these directions, offering empirically grounded examples and critical reflections that contribute to building a more responsive and future-ready framework for language learning and communication support.

Advancing the evidence base for VR interventions in social communication disorder requires targeted methodological innovation and broader research scope. Priority directions include the conduct of rigorously designed randomised controlled trials to establish causal effects, the recruitment of larger and more diverse participant samples to enhance generalisability, and the systematic use of standardised, validated outcome measures to enable comparison across studies. Addressing the field's key research gaps will also necessitate studies focused on determining optimal intervention dosage and frequency, the examination of individual difference factors (such as age, cognitive profile, and baseline language skills) that may moderate intervention response, and direct comparisons of the effectiveness of VR-based interventions relative to traditional or hybrid approaches.

Given the rapid evolution of VR technology, future research should incorporate adaptive evaluation strategies and remain attuned to shifts in hardware, software, and user interface design that may affect accessibility, engagement, and outcomes. Establishing frameworks for ongoing monitoring and iterative assessment will be crucial to maintaining the relevance of evidence as the technological landscape evolves. By addressing these methodological priorities, the field will be well-positioned to generate robust, generalisable, and clinically meaningful findings that can inform both practice and policy in the use of immersive technologies for social communication intervention.

## 5. Limitations

Despite the strengths of a systematic and transparent approach, several limitations of this review should be acknowledged.

The evidence base available for synthesis was limited both in quantity and in scope. Only a small number of studies met the stringent inclusion criteria, and the majority focused primarily on children with ASD rather than the full spectrum of SCD. As a result, findings may not be directly generalisable to populations with developmental language disorder (Ellis Weismer et al., 2021), neurological conditions (Jeste, 2011), or other forms of SCD, particularly in the CALD context (Han, 2015, 2020). The field itself remains emergent, and ongoing research may alter the landscape.

Considerable heterogeneity was observed across included studies in terms of intervention models, sample sizes, participant characteristics, VR platforms, and outcome measures. This diversity, while reflecting innovation and early-stage research, complicated direct comparisons and precluded formal meta-analysis or quantitative synthesis. Also, while comprehensive database searches and rigorous screening were undertaken, it is possible that some relevant studies were not identified due to publication language restrictions, the rapid evolution of VR technology, or indexing limitations in electronic databases. The review excluded conference abstracts, grey literature, and studies with single-subject designs or insufficiently detailed methodologies, which may have excluded some innovative or preliminary work.

Also, the predominance of immediate, post-intervention outcome measures and the lack of longitudinal follow-up data limited the review's ability to assess the durability and real-world generalisation of observed intervention effects. Similarly, the focus on controlled or clinical settings means that findings may not reflect the complexities of implementation in diverse community or educational environments. As VR technology evolves, findings may become outdated or require re-evaluation considering new platforms and user interfaces.

The thematic synthesis approach relied on qualitative interpretation and consensus-building among reviewers. While best-practice frameworks (Braun & Clarke, 2006; Thomas & Harden, 2008) were employed to enhance rigour, some degree of subjectivity is inherent in theme derivation and narrative synthesis.

Taken together, these limitations highlight the need for ongoing, methodologically robust, and inclusive research in this rapidly developing field. Future studies should aim for greater population diversity, standardised and ecologically valid outcome measures, longitudinal designs, formal quality appraisal, and direct investigation of underlying learning mechanisms. Despite these limitations, the present review offers a timely synthesis and identifies priority directions for advancing the evidence base in VR-supported interventions for social communication disorder.

## 6. Conclusions

Virtual reality represents a compelling shift in how we conceptualise, design, and deliver interventions for social communication challenges in children and adolescents. This review synthesises emerging evidence that positions VR not merely as a technological novelty, but as a pedagogically and clinically meaningful tool, i.e., one that creates immersive, personalised, and cognitively attuned learning environments. Across therapeutic and educational contexts, VR has shown the capacity to reduce social anxiety, support skill acquisition, and bridge the longstanding gap between simulated practice and real-world communication demands.

Yet, the promise of VR lies not just in its novelty but in how thoughtfully it is integrated into practice. Its success depends on more than hardware; it requires interdisciplinary collaboration, context-sensitive design, and robust evaluation frameworks that centre

the learner. As the field moves forward, equity of access, training for implementation, and support for sustainable uptake will be critical to ensuring VR's potential is fully realised. Future research should seek to expand the evidence base for VR interventions in children with developmental language disorders, neurological conditions, and other forms of SCD, ensuring that recommendations are responsive to population-specific strengths and needs. Such work will be essential for developing more nuanced, equitable, and effective approaches to social communication intervention across the full spectrum of neurodevelopmental diversity. To establish the clinical effectiveness and real-world value of VR-based interventions for SCD, the field must prioritise the development and adoption of standardised outcome measures and undertake rigorous longitudinal studies tracking skill generalisation over time.

This review hopes to offer a foundation for such progress and to signal a decisive step toward reimagining how immersive technologies can enhance language learning and communication development, which is advancing not only the field but also the futures of the diverse learners it seeks to serve.

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| ASD | Autism Spectrum Disorder |
| CVE | Collaborative Virtual Environment |
| DLD | Developmental Language Disorder |
| SCD | Social Communication Disorder |
| VR | Virtual Reality |

# Appendix A

**Table A1.** Summary of Key Research Themes and Findings.

| Themes | Studies | Objectives | Methodology | Main Findings | Implications | Gaps/Future Directions |
| --- | --- | --- | --- | --- | --- | --- |
| 1. Usability and Acceptability of VR in Social Communication Interventions | Gayle et al. (2024) | Examine the usability, generalisation, and acceptability of VR-based social and safety skills training. | Three children with ASD (ages 5–8) used the VR platform "Floreo" to practice crossing streets, animal identification, and safety skills. Skills were tested for maintenance and generalisation to natural environments. | VR successfully facilitated skill acquisition, which was maintained and generalised. High levels of happiness and positive engagement were observed during VR sessions. | VR can teach practical skills difficult to replicate in traditional therapy (e.g., street safety). | Scale up testing with larger samples. Investigate VR's efficacy for a wider range of social skills. |
| 1. Usability and Acceptability of VR in Social Communication Interventions. 4. Measurement and Assessment of Social Communication Skills in VR | Vaezipour et al. (2022) | To investigate clinicians' acceptance, barriers, and enablers of immersive VR technology in communication rehabilitation. | A mixed-method approach was used, involving surveys (System Usability Scale and Simulator Sickness Questionnaire) and semi-structured interviews with 15 speech-language pathologists (SLPs). | SLPs expressed positive attitudes towards VR, citing its ability to simulate realistic, personalised communication environments for therapy. Motion sickness was minimal, and system usability was rated average. Barriers included limited familiarity with VR, resource constraints, and concerns about integration into clinical workflows. | VR can simulate real-world communication scenarios, offering a valuable tool for the rehabilitation of individuals with communication disorders. Customisation to individual client needs is essential for effective implementation. | Further research on VR's clinical efficacy across diverse communication disorders. Address clinician training and accessibility barriers. Develop VR platforms tailored to specific rehabilitation goals. |
| 2. VR for Social Skills Training and Social Interaction in ASD | Alimanova et al. (2022) | Develop an immersive VR training system to improve social interaction and communication skills in children with ASD. | A virtual "Farm Trip" game was created using Oculus Quest 2. Face and speech recognition integrated with AI algorithms assessed emotional states and speech patterns. | The VR system provided realistic environments for practicing social interactions. Children engaged in repetitive tasks to adapt to new situations, improving communication and emotional expression. | VR can replicate safe, immersive environments for therapy, particularly during disruptions like COVID-19. | Test effectiveness with larger, diverse samples. Explore long-term engagement and therapy outcomes. |

**Table A1.** *Cont.*

| Themes | Studies | Objectives | Methodology | Main Findings | Implications | Gaps/Future Directions |
| --- | --- | --- | --- | --- | --- | --- |
| 2. VR for Social Skills Training and Social Interaction in ASD | Ke et al. (2022) | Explore the use of a VR-based learning environment to teach social skills to children with ASD. | Seven children (ages 10–14) participated in VR role-playing, gaming, and collaborative design tasks.<br>Data were collected through screen recordings and pre-/post-intervention social communication measures. | Significant improvement in social skills performance, including communication and cooperation.<br>Participants showed increased motivation and engagement. | VR provides a naturalistic and immersive setting for teaching complex social interactions. | Examine the role of VR in enhancing intrinsic social motivation.<br>Compare VR to other evidence-based social skills interventions. |
| 2. VR for Social Skills Training and Social Interaction in ASD | Zhao et al. (2018) | Develop and test a collaborative virtual environment (CVE) system to enhance social interaction in children with ASD. | In total, 12 children with ASD and 12 typically developing peers engaged in a series of interactive games.<br>The "Hand-in-Hand" system enabled collaborative activities using hand gestures, gaze-based communication, and voice commands. | Children with ASD demonstrated improved collaboration and communication skills.<br>Participants accepted the system well, and naturalistic interactions encouraged social reciprocity. | CVEs provide a low-cost, scalable intervention platform for peer-based social skills training. | Larger studies with a broader ASD population.<br>Assess long-term skill retention and real-world generalisation.<br>Develop adaptive systems for individual needs. |
| 2. VR for Social Skills Training and Social Interaction in ASD.<br>3. Gaze and Attention Tracking in VR for Social Communication | Bekele et al. (2016) | Develop a multimodal adaptive VR platform for social interaction training in ASD. | A virtual school cafeteria scenario was used with real-time eye tracking, EEG monitoring, and physiological sensors.<br>A total of 12 children with ASD participated in usability testing. | Eye gaze and task performance were successfully tracked to adapt interactions in real time.<br>Results showed that participants were able to improve emotional recognition and social interaction skills. | Integrating gaze and physiological data enhances personalised interventions. | Longitudinal studies to assess sustained improvements.<br>Broader testing with varying ASD severity levels. |
| 3. Gaze and Attention Tracking in VR for Social Communication | Lahiri et al. (2011) | Develop a VR-based system with gaze measurement technology to improve social communication in ASD. | A VR system presented social tasks while tracking eye-gaze patterns in real time.<br>Six adolescents with ASD participated in usability testing. | Real-time adaptive gaze feedback successfully modified participants' gaze behaviours.<br>Improved fixation on socially relevant cues, such as facial expressions. | Gaze-sensitive VR systems can enhance facial emotion processing in children with ASD. | Investigate long-term changes in gaze behaviours.<br>Assess skill transfer to real-world social settings. |

**Table A1.** *Cont.*

| Themes | Studies | Objectives | Methodology | Main Findings | Implications | Gaps/Future Directions |
| --- | --- | --- | --- | --- | --- | --- |
| 4. Measurement and Assessment of Social Communication Skills in VR | L. Zhang et al. (2020) | Develop and pilot an intelligent collaborative virtual environment (CRETA) to measure social communication in children with ASD. | CRETA was tested with children with ASD to track communication and collaboration skills during peer interactions. Automated analysis of social communication was compared with human analysis. | The system achieved moderate to high accuracy in measuring social communication. Results aligned well with human assessments, validating the system's accuracy. | Intelligent VR environments can autonomously assess and support social communication. | Extend validation across broader populations. Develop interventions based on real-time feedback from intelligent systems. |
| 5. VR for SCD in inclusive education | Arts et al. (2024) | To evaluate the feasibility and effectiveness of an interactive VR training program ("InterAction") for improving socio-emotional functioning in adolescents with Developmental Language Disorders (DLD). | A small-scale feasibility study with nine adolescents (ages 13–16) diagnosed with DLD. Participants completed six VR training sessions focusing on socio-emotional skills. | The VR training was feasible and well-received by participants, who reported high levels of enjoyment and a sense of presence in the virtual environment. Improvements in socio-emotional skills were observed, though results varied between participants and skill areas. | VR offers a promising tool for adolescents with DLD to practice socio-emotional skills in realistic, risk-free virtual scenarios. VR interventions reduce reliance on language-heavy approaches, making training accessible for children with language difficulties. | Larger, controlled studies are needed to confirm findings. Investigate the generalisation of skills to real-world settings. Examine individual differences influencing responsiveness to VR training. |
| 5. VR for SCD in inclusive education | Kolk et al. (2023) | To pilot a combined intervention (PowerVR) using multitouch-multiuser tabletops (MMT) and VR platforms to train social communication skills in children with neurological disorders. | Sixty children (ages 8–13) with neurological disorders (e.g., epilepsy, TBI) participated. Sixteen participants completed a 10-session intervention with pre- and post-assessments focusing on social communication components such as theory of mind (ToM), conflict resolution, and empathy. | Significant improvements were seen in communication, cooperation, pragmatics, social attention, and conflict resolution. ToM and false belief understanding notably improved. Participants experienced less bullying and displayed greater confidence in social interactions. | Combining MMT and VR provides a robust, multimodal approach for socio-emotional and communication training. Targeted interventions can improve specific deficits, such as empathy and ToM, in children with neurological conditions. | Expand the study with larger sample sizes and diverse populations. Explore long-term retention of improvements. Assess the comparative effectiveness of PowerVR against traditional therapies. |

**Table A1.** *Cont.*

| Themes | Studies | Objectives | Methodology | Main Findings | Implications | Gaps/Future Directions |
| --- | --- | --- | --- | --- | --- | --- |
| 5. VR for SCD in inclusive education | Vairamani et al. (2024) | To examine how augmented reality (AR) and virtual reality (VR) technologies enhance social skills development in children with special needs, including those with communication challenges. | Theoretical frameworks, literature reviews, and case studies were used to explore AR and VR applications. Techniques such as virtual role-playing, empathy-building, and collaborative VR environments were highlighted. | AR and VR provide immersive, interactive simulations for practising social interactions in a safe, controlled environment. Key features include fostering empathy, improving non-verbal communication, and providing real-time feedback on social behaviours. These technologies encourage engagement and increase the transfer of practised skills to real-world contexts. | AR/VR can be integrated into special education and therapy programs to create highly tailored interventions for improving social skills. | Conduct longitudinal studies to assess long-term impacts. Develop socially aware virtual agents. Investigate ethical and accessibility issues. Integrate AR/VR with other therapeutic approaches. |

## References


Abeillé, A., Hemforth, B., Winckel, E., & Gibson, E. (2020). Extraction from subjects: Differences in acceptability depend on the discourse function of the construction. *Cognition*, *204*, 104293. [CrossRef]

Alfadil, M. (2024). Immersive virtual reality: A novel approach to second language vocabulary acquisition in K-12 education. *Sensors*, *24*(22), 7185. [CrossRef]

Alimanova, M., Soltiyeva, A., Urmanov, M., & Adilkhan, S. (2022, April 28–30). *Developing an immersive virtual reality training system to enrich social interaction and communication skills for children with autism spectrum disorder*. 2022 International Conference on Smart Information Systems and Technologies (SIST), Nur-Sultan, Kazakhstan.

Arts, E., De Castro, B. O., Luteijn, E., Elsendoorn, B., & Vissers, C. T. W. M. (2024). Interactive virtual reality training to improve socio-emotional functioning in adolescents with developmental language disorders: A feasibility study. *Clinical Child Psychology and Psychiatry*, *29*(3), 1100–1120. [CrossRef] [PubMed]

Bekele, E., Wade, J., Bian, D., Fan, J., Swanson, A., Warren, Z., & Sarkar, N. (2016, March 19–23). *Multimodal adaptive social interaction in virtual environment (MASI-VR) for children with Autism spectrum disorders (ASD)*. 2016 IEEE Virtual Reality (VR), Greenville, SC, USA.

Bohlander, A. J., Orlich, F., & Varley, C. K. (2012). Social skills training for children with autism. *Pediatric Clinics of North America*, *59*(1), 165–174. [CrossRef]

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. [CrossRef]

Cheng, Y., Huang, C.-L., & Yang, C.-S. (2015). Using a 3D immersive virtual environment system to enhance social understanding and social skills for children with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, *30*(4), 222–236. [CrossRef]

Dawson, G., & Burner, K. (2011). Behavioral interventions in children and adolescents with autism spectrum disorder: A review of recent findings. *Current Opinion in Pediatrics*, *23*(6), 616–620. [CrossRef] [PubMed]

Durlak, J. A., Mahoney, J. L., & Boyle, A. E. (2022). What we know, and what we need to find out about universal, school-based social and emotional learning programs for children and adolescents: A review of meta-analyses and directions for future research. *Psychological Bulletin*, *148*(11–12), 765–782. [CrossRef]

Eadie, P., Conway, L., Hallenstein, B., Mensah, F., McKean, C., & Reilly, S. (2018). Quality of life in children with developmental language disorder. *International Journal of Language & Communication Disorders*, *53*(4), 799–810. [CrossRef]

Ellis Weismer, S., Tomblin, J. B., Durkin, M. S., Bolt, D., & Palta, M. (2021). A preliminary epidemiologic study of social (pragmatic) communication disorder in the context of developmental language disorder. *International Journal of Language & Communication Disorders*, *56*(6), 1235–1248. [CrossRef]

Furukawa, K., & Nakamura, S. (2024). Boundary-driven downstep induced by syntax-prosody mapping. *The Journal of the Acoustical Society of America*, *156*(2), 1440–1460. [CrossRef]

Gayle, R. I., Valentino, A. L., & Fuhrman, A. M. (2024). Virtual reality training of safety and social communication skills in children with autism: An examination of acceptability, usability, and generalization. *Behavior Analysis in Practice*, *18*(1), 179–195. [CrossRef]

Gottlieb, M., Haas, M. R. C., Daniel, M., & Chan, T. M. (2021). The scoping review: A flexible, inclusive, and iterative approach to knowledge synthesis. *AEM Education and Training*, *5*(3), e10609. [CrossRef]

Hage, S. V. R., Sawasaki, L. Y., Hyter, Y., & Fernandes, F. D. M. (2021). Social Communication and pragmatic skills of children with autism spectrum disorder and developmental language disorder. *Codas*, *34*(2), e20210075. [CrossRef]

Han, W. (2013). *Word order typology: Topic and topic marker structure*. Shanghai Foreign Language Education Press.

Han, W. (2015). First language bidialectism and associative learning in second language acquisition. *Studies in English Language Teaching*, *3*(1), 65–72. [CrossRef]

Han, W. (2020). Cross-linguistic transfer and second language learnability. In W. Han (Ed.), *Universal grammar and the initial state of second language learning: Evidence of Chinese multidialectal children's acquisition of english at the syntax-semantics interface* (pp. 17–25). Springer. [CrossRef]

Han, W., Brebner, C., & McAllister, S. (2016). Redefining 'Chinese' L1 in SLP-considerations for the assessment of Chinese bilingual-bidialectal language skills. *International Journal of Speech-Language Pathology*, *18*(2), 135–146. [CrossRef]

Han, W., & Shi, D. (2016). Topic and left periphery in Shanghainese. *Journal of Chinese Linguistics*, *44*(1), 29–60. [CrossRef]

Ip, H. H. S., Wong, S. W. L., Chan, D. F. Y., Byrne, J., Li, C., Yuan, V. S. N., Lau, K. S., & Wong, J. Y. (2018). Enhance emotional and social adaptation skills for children with autism spectrum disorder: A virtual reality enabled approach. *Computers & Education*, *117*, 1–15. [CrossRef]

Javaid, M., Haleem, A., Singh, R. P., & Dhall, S. (2024). Role of Virtual Reality in advancing education with sustainability and identification of Additive Manufacturing as its cost-effective enabler. *Sustainable Futures*, *8*, 100324. [CrossRef]

Jeste, S. S. (2011). The neurology of autism spectrum disorders. *Current Opinion in Neurology*, *24*(2), 132–139. [CrossRef]

Ke, F., Moon, J., & Sokolikj, Z. (2022). Virtual reality–based social skills training for children with autism spectrum disorder. *Journal of Special Education Technology*, *37*(1), 49–62. [CrossRef]

Kolk, A., Saard, M., Roštšinskaja, A., Sepp, K., & Kööp, C. (2023). Power of combined modern technology: Multitouch-multiuser tabletops and virtual reality platforms (PowerVR) in social communication skills training for children with neurological disorders: A pilot study. *Applied Neuropsychology: Child*, *12*(3), 187–196. [CrossRef] [PubMed]

Kouijzer, M. M. T. E., Kip, H., Bouman, Y. H. A., & Kelders, S. M. (2023). Implementation of virtual reality in healthcare: A scoping review on the implementation process of virtual reality in various healthcare settings. *Implementation Science Communications*, *4*(1), 67. [CrossRef]

Lahiri, U., Warren, Z., & Sarkar, N. (2011, June 27–29). *Dynamic gaze measurement with adaptive response technology in Virtual Reality based social communication for autism*. 2011 International Conference on Virtual Rehabilitation, Zurich, Switzerland.

Logan, K., Iacono, T., & Trembath, D. (2017). A systematic review of research into aided AAC to increase social-communication functions in children with autism spectrum disorder. *Augmentative and Alternative Communication*, *33*(1), 51–64. [CrossRef]

Marshall, T. (2019). The concept of reflection: A systematic review and thematic synthesis across professional contexts. *Reflective Practice*, *20*(3), 396–415. [CrossRef]

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press. [CrossRef]

Morgan, D. L., & Nica, A. (2020). Iterative thematic inquiry: A new method for analyzing qualitative data. *International Journal of Qualitative Methods*, *19*, 1609406920955118. [CrossRef]

Nordin, V., Palmgren, M., Lindbladh, A., Bölte, S., & Jonsson, U. (2024). School absenteeism in autistic children and adolescents: A scoping review. *Autism*, *28*(7), 1622–1637. [CrossRef] [PubMed]

Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science*, *32*(1), 1–8. [CrossRef]

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., A Akl, E., E Brennan, S., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021a). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. [CrossRef] [PubMed]

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … McKenzie, J. E. (2021b). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*, *372*, n160. [CrossRef]

Peters, M. D. J., Marnie, C., Colquhoun, H., Garritty, C. M., Hempel, S., Horsley, T., Langlois, E. V., Lillie, E., O'bRien, K. K., Tunçalp, Ö., Wilson, M. G., Zarin, W., & Tricco, A. C. (2021). Scoping reviews: Reinforcing and advancing the methodology and application. *Systematic Reviews*, *10*(1), 263. [CrossRef]

Pollock, D., Tricco, A. C., Peters, M. D. J., McLnerney, P. A., Khalil, H., Godfrey, C. M., Alexander, L. A., & Munn, Z. (2022). Methodological quality, guidance, and tools in scoping reviews: A scoping review protocol. *JBI Evidence Synthesis*, *20*(4), 1098–1105. [CrossRef]

Saul, J., Griffiths, S., & Norbury, C. F. (2023). Prevalence and functional impact of social (pragmatic) communication disorders. *Journal of Child Psychology and Psychiatry*, *64*(3), 376–387. [CrossRef]

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*(2), 257–285. [CrossRef]

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*, *8*(1), 45. [CrossRef] [PubMed]

Tierney, C. D., Kurtz, M., Panchik, A., & Pitterle, K. (2014). 'Look at me when I am talking to you': Evidence and assessment of social pragmatics interventions for children with autism and social communication disorders. *Current Opinion in Pediatrics*, *26*(2), 259–264. [CrossRef] [PubMed]

Topal, Z., Demir Samurcu, N., Taskiran, S., Tufan, A. E., & Semerci, B. (2018). Social communication disorder: A narrative review on current insights. *Neuropsychiatric Disease and Treatment*, *14*, 2039–2046. [CrossRef]

Vaezipour, A., Aldridge, D., Koenig, S., Theodoros, D., & Russell, T. (2022). "It's really exciting to think where it could go": A mixed-method investigation of clinician acceptance, barriers and enablers of virtual reality technology in communication rehabilitation. *Disability and Rehabilitation*, *44*(15), 3946–3958. [CrossRef]

Vairamani, A. D., Devi, V. A., Singh, W., Kumar, Y., Kumar, Y., Ajantha Devi, V., & Singh, W. (2024). *Enhancing social skills development through augmented reality (AR) and virtual reality (VR) in special education* (pp. 65–89). John Wiley & Sons, Incorporated. [CrossRef]

Zhang, F., Zhang, Y., Li, G., & Luo, H. (2024). Using virtual reality interventions to promote social and emotional learning for children and adolescents: A systematic review and meta-analysis. *Children*, *11*(1), 41. [CrossRef]

Zhang, L., Weitlauf, A. S., Amat, A. Z., Swanson, A., Warren, Z. E., & Sarkar, N. (2020). Assessing social communication and collaboration in autism spectrum disorder using intelligent collaborative virtual environments. *Journal of Autism and Developmental Disorders*, *50*(1), 199–211. [CrossRef]

Zhao, H., Swanson, A. R., Weitlauf, A. S., Warren, Z. E., & Sarkar, N. (2018). Hand-in-hand: A communication-enhancement collaborative virtual reality system for promoting social interaction in children with autism spectrum disorders. *IEEE Transactions on Human-Machine Systems*, *48*(2), 136–148. [CrossRef] [PubMed]

Zhi, Y., & Wu, L. (2023). Extended reality in language learning: A cognitive affective model of immersive learning perspective. *Frontiers in Psychology*, *14*, 1109025. [CrossRef] [PubMed]