Enhancing User Experience in Virtual Reality for Children with Autism: A Significant Review

Nur Aleesya Mohd Asri[1], Normala Rahim[2*], Norsuhaily Abu Bakar[3],
Wan Rizhan[4], Ismahafezi Ismail[5], Nur Saadah Mohd Shapri[6], Sarah Farhana Juhari[7]
Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Besut, Terengganu, Malaysia[1, 2, 4, 5, 6]
Faculty of Applied Social Science, Universiti Sultan Zainal Abidin, Gong Badak, Terengganu, Malaysia[3]
Malaysia Digital Economy Corporation (MDEC), Cyberjaya, Selangor[7]

***Abstract*—Virtual reality (VR) has become a promising technology to assist children with autism spectrum disorder (ASD especially in the areas of improving user experience with immersive, adaptive, and interactive environments. Nevertheless, current research is still disjointed in areas with very little synthesis on the effectiveness of VR in enhancing user experience and supporting the various cognitive, behavioural, and sensory requirements of autistic children. This study seeks to thoroughly review and synthesize current developments in VR-based solutions to determine the main methods, assessment plans, and design implications that can enhance user experience in this population. The systematic literature review was based on the PRISMA framework, where an advanced search strategy was implemented in Scopus and IEEE databases with keywords related to autism, user experience, and virtual reality. The identification phase yielded 939 records, followed by a rigorous screening and eligibility process resulting in a final dataset of 29 primary studies published between 2020 and 2025. The results were divided into three broad themes, namely: 1) VR-Based Intervention and Skill Development for Autism which shows how social, cognitive and daily living skills can be improved with the help of an immersive training; 2) Assessment, Evaluation and Multimodal Analytics in VR for Autism which reveals how objective evaluation and personalisation can be achieved with the assistance of behavioural and physiological and AI driven data which can improve the evaluation and personalization; and 3) Design Framework which includes VR system for Autism that focuses on users, ethical consideration and an inclusive system development. Altogether, the review indicates that VR demonstrates substantial potential to improve the user experience of children with autism, especially when it is facilitated through adaptive, data-driven, and inclusive design strategies. However, issues of scalability, long-term efficacy, and standardisation persist, meaning that future studies are required to create strong and user-friendly VR frameworks in this population.**

***Keywords*—Virtual Reality (VR); Autism Spectrum Disorder (ASD); User Experience (UX); multimodal analytics; inclusive design**

I. Introduction

Virtual Reality (VR) is a technology that simulates lifelike and immersive experiences within a digitally created environment. Objects within VR tend to behave much as they do in the physical world, allowing users to engage with them in a manner that follows natural laws of physics [1], [2]. Hence, it has emerged as a groundbreaking technology in therapeutic and educational interventions in children with autism spectrum disorder (ASD) and offers immersive and interactive environments that can be tailored to particular needs. The role of user experience (UX) in this context is immeasurable, and the success of VR-based interventions depends on how well they can address the specific sensory, cognitive, and social aspects of autistic children. The increasing prevalence of ASD, together with limitations in traditional therapeutic approaches, has led to the rise of interest in applying VR to support social communication, emotional regulation, and adaptive behavior. However, the possibility of VR is limited by the difficulty of developing a digital space that is appealing and favorable to children with different sensory backgrounds and interaction. The review presents the current body of research on the usefulness of UX enhancement in VR among autistic children, focusing on the connections between theoretical assumptions and technological innovation and the practical implementation of this methodology in a clinical setting and in the educational process. [3], [4], [5].

Autistic children are known to have abnormal sensory processing behavior where they experience hyper or hyposensitivity to visual, auditory, and tactile stimuli [6]. Such sensory differences can greatly influence their tolerance and acclimatization to VR environments, where uncontrolled or excessive stimulation can result in distress, anxiety or disengagement [7]. Repeated studies have demonstrated that personalised sensory modulation, such as manipulation of the intensity, type and timing of sensory input may be used to alleviate sensory overload and facilitate a positive interaction. [8] Indicatively, VR systems as screens, delivering controlled multimodal stimuli have been shown to be tolerable to autistic adolescents and have been shown to have behavioral responses, which are correlated to individual sensory profiles [9], [10], [11]. Moreover, the emotional factors play a decisive role in the sensory responsiveness, and tactile hyper- or hypo-responsivity is typically coupled with anxiety or disparities in emotional processing in comparison with the mere perceptual incompetence [12], [13]. The VR design that is effective in this population is therefore not only technically precise in terms of sensory delivery but also ought to be sensitive to the emotional and behavioral context in which senses are utilized. [1]

The presence of engagement barriers and preferences for interaction further complicates the design of VR for autistic children. ASD children prefer natural, effective modalities of interaction, such as virtual hand controls or gesture interfaces, to formal game controllers, which can lessen cognitive load and

*Corresponding author.

improve task performance [14], [15]. Engagement may, however, be destroyed by unpredictability, multifaceted social signals and the danger of sensory bombardment necessitating predictable and adaptable contexts. VR worlds can be modified on-the-fly, depending upon physiological and behavioral feedback such as eye tracking and heart rate to make interventions more personalized and enable long-term engagement [16], [17]. Autistic children, educators and therapists have also been mentioned as critical in the co-design strategies, where they are involved in the development process and can create inclusive, comfortable and motivating VR experiences [18], [19]. Such participatory practices not only increase usability but also tackle ethical issues by making sure that interventions are respectful, relevant, and in line with the lived experiences of autistic users [20], [21].

VR technology in ASD is varied and includes a variety of hardware platforms such as head-mounted displays (HMDs) and desktop and projector-based systems, each with its own strengths and weaknesses. The interaction provided by an immersive VR using HMDs tends to be more engaging and spatial and can fit the visuospatial advantages of most autistic children [22], [23]. They may, however, also increase sensory sensitivities and cause cybersickness, especially in individuals with a high perceptual sensitivity, requiring specific desensitization measures and session control [24]. Less immersive or screen-based VR can provide a more accessible option to younger or more sensitive users but could potentially come at the cost of decreased immersion and engagement [24], [25]. On all platforms, customizable sensory parameters, spatialized audio, haptics and real-time adaptation frameworks are critical to lessening sensory overburden and maximizing therapeutic value [11], [17]. The evidence base of the VR interventions in ASD is strong and demonstrates the short-term outcomes of the interventions in improving social communication, cognitive and adaptive behaviors, yet there are still methodological limitations such as small sample sizes, lack of diversity and follow-ups [26], [27], [28].

Nevertheless, despite the potential of VR, significant research and technological gaps remain. The rigor of the methodology is often subpar, and the majority of the studies rely on small and homogeneous samples and short-term outcome measurements, limiting the possibility of generalizing and scaling up the findings [27], [28]. VR used together with established types of therapy, such as cognitive behavioral therapy, has been shown to have a synergistic effect on enhancing social, cognitive and emotional outcomes, although more systematic studies are still required to identify best practice and long-term effectiveness [29], [30]. The issue of the sensory overload, cybersickness, privacy, consent and the risk of interventions trying to normalize autistic characteristics rather than letting people be themselves are of paramount importance [20], [31]. The participatory design model and responsible research and innovation models are also increasingly mentioned as a requirement to ensure that VR technologies are created and implemented in a way that is both safe, inclusive and responsive to the needs of autistic children [21], [31]. Price, infrastructure, teacher education and individualized content barriers to greater implementation in education and clinical practice should also be surmounted through collaborative, user-friendly innovation and policy facilitation [32], [33].

This systematic review aims to address these gaps and is structured into several sections to provide a systematic understanding of virtual reality applications for children with autism. The next section of this study presents the research methodology based on the PRISMA framework, including the search strategy, screening criteria, eligibility process, and quality assessment procedures. Mixed Methods Appraisal Tool (MMAT) was conducted to evaluate the methodological quality of included studies and distinguish between high-quality and low-quality evidence. This is followed by the results and findings section, which discusses publication trends and thematic analysis derived from the selected studies. The thematic findings are categorized into three major themes: VR-based intervention and skill development, multimodal assessment and analytics, and inclusive design frameworks for autism-related VR systems. Finally, the discussion and conclusion section summarizes the key findings, highlight the practical and theoretical implications of the review, identifies current limitations, and proposes future research directions for enhancing user experience in VR environments for children with autism.

Overall, enhancing user experience in virtual reality for children with autism requires an integrative approach that bridges technical innovation with a comprehensive understanding of autistic users' sensory, cognitive, and emotional needs. In the literature, having personalized, adaptive VR spaces to embrace individual sensory profiles, leverage natural interaction patterns and co-created with people and stakeholders is emphasized to be relevant, both ethically and practically. Despite the gigantic potential of immersive VR technologies to improve social, cognitive and emotional outcomes, the utility of the latter should be justified by a serious methodological analysis, their confirmation by a certain time and developing the means of their implementation, which should be scalable and accessible. Further research is required to be more specific to the application of a wide range of population groups of participants, employing powerful longitudinal designs and integrating machine learning and real-time feedback systems that can help to further customize and optimize VR experiences. Finally, the fulfilment of the promise of VR to help autistic children will require long-term interdisciplinary cooperation, ethical responsibility and a focus on participatory and user-centered design [34], [35].

II. Materials and Methods

A. Identification

According to the PRISMA framework, the identification phase is a fundamental step to the comprehensiveness and transparency of a systematic literature review (SLR). Table I demonstrates that a systematic and thorough search approach was carried out in two major and complementary academic sources, including Scopus and IEEE Xplore, on a mixture of keywords regarding autism, user experience, and virtual reality. The initial search led to a total of 939 records, including 757 in Scopus and 182 in IEEE.

Such a distribution is suggestive of Scopus as a more comprehensive source of disciplinary coverage because it indexes a wide range of journals not only in the health sciences but also in psychology and the social sciences, and also in studies in technology. On the other hand, the IEEE Xplore is more technical and engineering-based and therefore offers a smaller scope of literature. The fact that there were a comparatively higher number of records found in Scopus indicates that the research on virtual reality applications in children with autism is not restricted to technical research but is extensively studied within the context of interdisciplinary research, including human-computer interaction, rehabilitation and educational technology.

TABLE I. SEARCH STRING

Scopus	TITLE-ABS-KEY (("autism" OR "autistic disorder" OR "autistic spectrum disorder" OR "ASD") AND ("virtual reality" OR "VR" OR "immersive technology" OR "simulated environment") AND ("user experience" OR "UX" OR "user-centered design" OR "interaction" OR "engagement")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , "2020") OR LIMIT-TO (PUBYEAR , "2022") OR LIMIT-TO (PUBYEAR , "2023") OR LIMIT-TO (PUBYEAR , "2024") OR LIMIT-TO (PUBYEAR , "2025")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (OA , "all")) Date of Access: April 2026
IEEE	("autism" OR "autistic disorder" OR "autistic spectrum disorder" OR "ASD") AND ("virtual reality" OR "VR" OR "immersive technology" OR "simulated environment") AND ("user experience" OR "UX" OR "user-centered design" OR "interaction" OR "engagement") Date of Access: April 2024

B. Screening

The screening is a critical filtering step of the SLR process, which aims at narrowing down the records that had been identified during the initial stage by using preset inclusion and exclusion criteria. In this study, the rigorous screening process was implemented to determine the relevance, quality, and disciplinary suitability of the literature selected. Table II shows the selection criterion of the articles reviewed.

Besides procedural filtering, the screening judgments have substantial methodological implications and reasons. English-language publication restriction enhances interpretability and consistency in data extraction but may result in some degree of language bias by excluding potentially valuable local studies. Similarly, ensuring that the time frame remains the publications after 2020 is a way to ensure that the review incorporates the latest technological changes and current UX practices in virtual reality, which is one of the rapidly evolving spheres. Such exclusion of conference papers and reviews, possibly having omitted early-stage innovations and synthesized knowledge, supports the bias of the review toward fully developed and high-impact journal contributions. In addition, the subject areas being narrow ensure conceptual consistency and no watering down of findings by irrelevant fields. The second step of removing 12 duplicate records indicates the importance of cross-database integration and data cleaning to avoid overrepresentation of the same studies. Collectively, these screening procedures lead to enhanced internal validity, transparency and reproducibility of the review, not to mention that they are an indicator of purposeful strike of inclusiveness and methodological rigor, which are all necessary in producing high-quality results of an SLR.

TABLE II. THE SELECTION CRITERION IS SEARCHING

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2020-2025	<2020
Literature Type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

C. Eligibility

The eligibility stage further narrows down the filtered records by evaluating their substantive conformity to the study aims and obtaining full data to analyze. Among the 264 articles that were evaluated in terms of full-text analysis, only a significant portion of them (n=235) were eliminated according to the clearly defined criteria, such as articles that were not relevant to the research area in general, abstracts that were not related to the main objectives of the study, and those articles that were not accessible in terms of full-text assessment. This step acts as a rather important quality control gateway whereby only the studies that are directly conceptually and empirically related to the user experience in virtual reality in the context of autism are left. As a result, the resulting corpus was reduced to 29 studies that could be included in qualitative synthesis, which is a very selective but focused corpus.

D. Quality Assessment

To evaluate the methodological rigor of included studies and distinguish between high-quality and low-quality evidence, a quality assessment was conducted using the Mixed Methods Appraisal Tool (MMAT) version 2018. The MMAT is a validated instrument designed to appraise the methodological quality of five categories of studies: qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed methods studies.

Each study was independently assessed by two reviewers using the appropriate MMAT criteria for its study design. The MMAT uses a set of screening questions followed by category-specific quality criteria. Studies are not assigned an overall numerical score; instead, the detailed responses to each criterion provide a comprehensive quality profile.

1) Quality assessment results of the 29 included studies:

- 8 studies (27.6%) met all applicable MMAT quality criteria, indicating high methodological rigor.
- 15 studies (51.7%) met most criteria with minor limitations.
- 6 studies (20.7%) had moderate methodological limitations.

No studies were excluded based on quality assessment; however, the quality ratings informed the interpretation and synthesis of findings. Studies with higher methodological rigor were given greater weight in the critical analysis, and limitations of lower-quality studies were explicitly noted in the thematic synthesis. The quality assessment results are summarized in Table III.

TABLE III. QUALITY ASSESSMENT SUMMARY USING MMAT

Quality Category	Number of Studies	Percentage	Key Characteristics
High Quality	8	27.6%	Met all applicable MMAT criteria; rigorous design, clear methodology, appropriate analysis
Moderate-High Quality	15	51.7%	Met most criteria with minor limitations; generally sound methodology with small gaps
Moderate Quality	6	20.7%	Notable methodological limitations; findings interpreted with caution

Common methodological strengths across high-quality studies included clear research questions, appropriate study designs, detailed descriptions of VR systems and interventions, validated outcome measures, and transparent reporting of limitations. Common weaknesses in moderate-quality studies included small sample sizes without justification, lack of control or comparison groups, limited generalizability, and insufficient detail on data analysis.

E. Data Abstraction and Analysis

The approach used in this research is an integrative analysis as it is one of the assessment methods that a researcher employs to conduct a systematic examination and synthesis of the results of varied qualitative research designs. The main aim of this strategy was to determine the overall themes and sub-themes that apply to Enhancing User Experience in Virtual Reality among Autistic children. The process started with the collection of data that formed the basis for the development of themes. The authors performed a thorough and repeated analysis of 29 chosen publications, deriving meaningful statements and evidence that were directly relevant to the study focus, as shown in Fig. 1. The studies were critically reviewed regarding their methodology and main findings to get a full picture of the existing research in the field.

The authors then held joint discussions to elaborate and develop themes based on the evidence retrieved. During the analysis, a systematic log was kept to record interpretations, emerging ideas, uncertainties, and analytical thoughts which would promote transparency and traceability. The authors constantly cross-tabulated the results of the studies in order to detect and eliminate inconsistencies in developing themes. Whenever there was a disagreement, consultations were held among the authors until they reached an agreement. The last themes were further developed to make them coherent and consistent. In order to enhance the validity and domain relevance of the thematic analysis, the identified themes were reviewed by two experts by evaluating the clarity, conceptual relevance, and consistency of the thematic categorization. Their feedback contributed to refining the analytical structure and improving the rigor and reliability of the thematic synthesis.

This study is guided by the following research questions.

1) How does virtual reality-based intervention influence user experience and skill development among children with autism in immersive learning environments?

2) How do multimodal data and evaluation techniques in virtual reality environments support the assessment of user experience and behavioral responses in children with autism?

3) What design principles and framework characteristics contribute to enhancing user experience in inclusive virtual reality systems for children with autism?

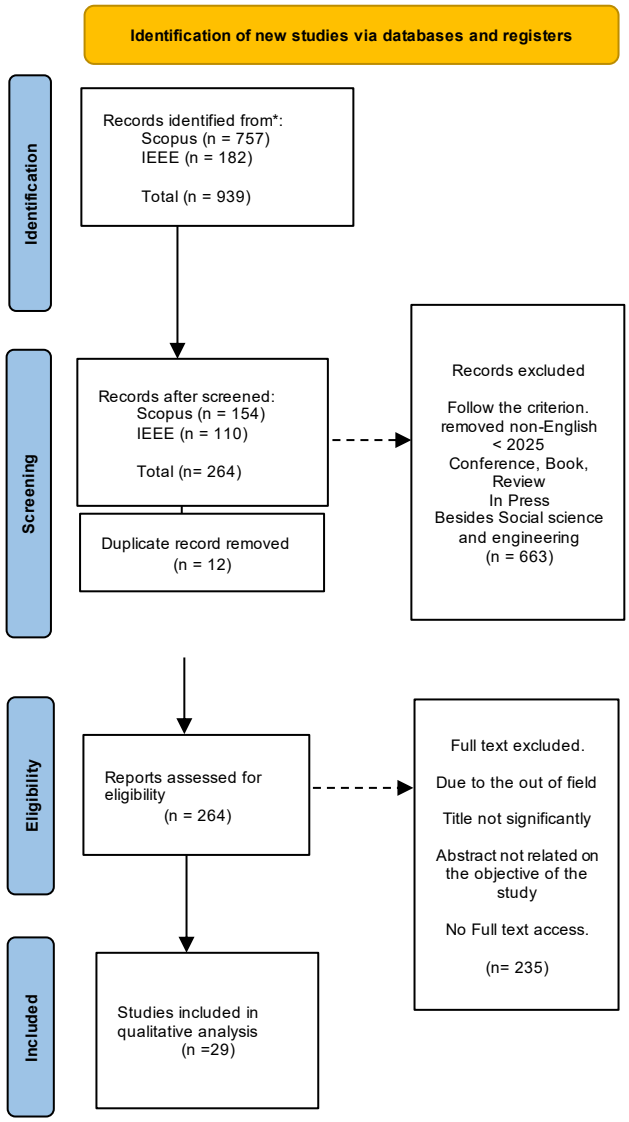

Fig. 1. PRISMA flow diagram of the proposed search study.

III. RESULTS AND FINDINGS

The following section presents the results of the systematic literature review according to the 29 selected studies that met the inclusion and quality assessment criteria. The results are divided into two broad sections: 1) an overview of the publication trends and the extracted properties of the reviewed articles, and 2) thematic analysis of the theme Enhancing user experience in Virtual Reality for Children with Autism.

A. Publication Trend and Synthesized Overview

1) Publication trend by year: Fig. 2, illustrating the temporal distribution of the reviewed articles, depicts that there is an overall increasing tendency of research output between 2020 and 2025 with several fluctuations. Publications began to decrease in 2020 (n=5), 2021 (n=3), and increased in 2022 (n=6) and 2023 (n=5), with a slight decrease in each year. It has a stronger upward trend with a greater increase in 2024 (n=9) and a high level of increase in 2025 (n=12). This trend is indicative of an increase in academic interest in integrating virtual reality (VR), user experience and interventions based on autism. The initial variability of 2020-2023 could be explained by the exploratory character of initial research and external factors like the COVID-19 pandemic that disrupted research and access to experimental conditions. This sudden increase as of 2024 will probably be fuelled by the fast development in VR technology such as more affordable and accessible hardware, and the growing recognition of the significance of personalized and immersive interventions in children with autism. In addition, the increased funding of research and interdisciplinary work in fields like digital health and assistive technologies could have led to this increase. On the whole, the upward trend indicates that the sphere transforms into less of an emerging field and more of a more mature and established one, where the focus is more on evidence-based design, user-centered solutions, and multimodal interaction in VR systems to support children with autism.

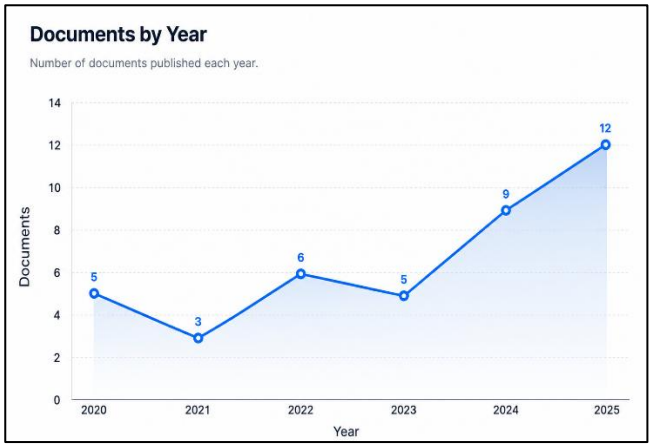

Fig. 2. Documents by year.

2) Documents by author: As Fig. 3 shows, the articles finally selected were distributed relatively widely and diffusely in terms of authorship, and the contribution of several authors was repeated quite a few times. It is interesting to note that Jung, S., Mei, C., and Moon, J. were the most frequent authors with two publications each, and the other authors had a single publication. This means that no single or small group of scholars dominates the field, but it is characterized by a large range of contributors. This may be because of the presence of recurrent authors, as this may be interpreted as a sign of nascent collaborative organizations or research partnerships, potentially being interdisciplinary collaboration between areas such as virtual reality, human-computer interactions, and autism research. The reason why these partnerships are so important is that they merge technical innovation and clinical and consumer-based perspectives. Overall, the trend is that the research area is still forming and that the number of contributors is growing but has not yet solidified, which implies that it is an emerging field where various contributions are being made to enhance research development, but it may be required to have more solid networks of collaboration to enhance research maturity and sustainability.

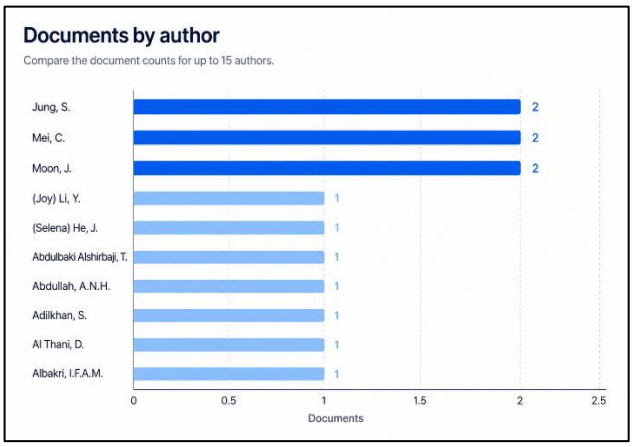

Fig. 3. Documents by author.

3) Documents by country: Fig. 4 demonstrates that the geographical pattern of the identified studies indicates a high level of concentration of the research production in several most productive countries, the United States (n=17) is the most productive country, and China (n=4) comes next. Other nations have a moderate contribution (n=3 each on average) with Argentina, Greece, Italy, and Norway being underrepresented (n=2 each). The supremacy of the United States is explained by the abundance of technological infrastructure, the high level of research investments, and the developed healthcare and educational systems in which the emphasis is put on the innovative interventions towards the developmental disorders. Likewise, the rise in contribution of China is indicative of its rise in investment in new technology like VR and digital health. By comparison, the smaller and more disjointed input of the Malaysian and other Asian nations indicates that, although interest in the region is increasing, research activities are less organized and could be limited by a lack of funds, infrastructural differences, and differences in healthcare priorities. On the whole, the field proves to be geographically uneven although it is geographically participatory with a prevalence in developed areas. This disparity explains why increasing international cooperation and capacity building is essential to make more inclusive and context-dependent improvements, especially in those areas that are underrepresented, and VR-based interventions may be of great assistance to children with autism.

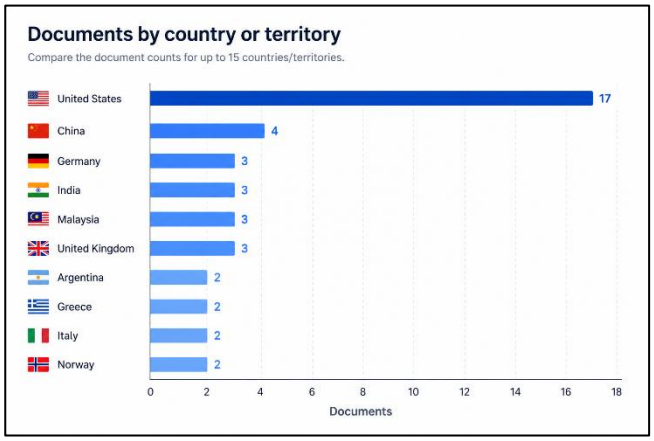

Fig. 4. Documents by country or territory.

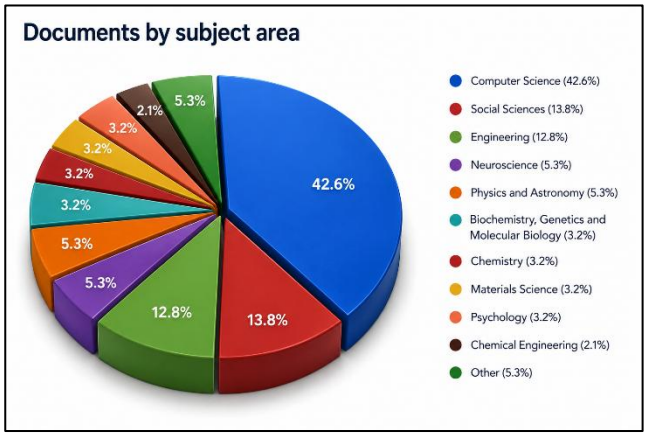

Fig. 5. Documents by subject area.

4) Documents by subject area: As Fig. 5 demonstrates, the choice of the articles by subject area reveals that computer science (42.6 percent) is highly prevalent, indicating that the creation of virtual reality (VR) technologies and the design of interactions are the most fundamental basis of this research area. This is followed by social sciences (13.8%), engineering (12.8%), which specializes in user-centered design, usability, and system development. Other smaller groups are neuroscience (5.3%), physics and astronomy (5.3%), and shares of psychology, biochemistry, chemistry, materials science and chemical engineering (all about 23). The value of cognitive, behavioral and sensory processing attributes in children with autism is indicative of psychology, neuroscience, engineering and physical sciences, which contribute to the hardware engineering, simulation and optimization of the systems. This interdisciplinary spread shows that the enhancement of user experience in VR in children with autism cannot be attributed to a single domain but instead, it requires the use of technological innovation in combination with clinical, behavioral and social strategies. Such collaboration enables the development of more detailed and effective solutions, as computer scientists are involved in the development of immersive systems, psychologists and the sphere related to healthcare ensure the relevance and usefulness of the interventions, and social sciences advise us on usability and accessibility issues. Overall, the overlap of the different areas contributed to the improvement of the research as it enables the creation of holistic design solutions, makes VR interventions more relevant and applicable, and allows taking a closer look at the ways of immersive technologies usage in addressing the needs of children with autism.

B. Thematic Findings

This section reviews the findings of the systematic literature review on the research questions and places them in the wider context of Enhancing User Experience in Virtual Reality with Autistic Children. These results highlight the main contributions, limitations, and future research and practice implications. Table IV presents the selected studies categorized according to the identified themes.

TABLE IV. THEMATIC CATEGORIZATION OF SELECTED STUDIES

Themes	#	Article Title	Ref
Theme 1: VR-Based Intervention and Skill Development for Autism	1	An Exploratory Analysis of Increasing Self-Efficacy of Adults with Autism Spectrum Disorder through the Use of Multimedia Training Stimuli	[35]
	2	Impact of virtual reality learning environments on skills development in students with ASD	[36]
	3	Combining Virtual Reality Visual Novels and Social Stories to Support Social and Emotional Development in Children with Autism Spectrum Disorder	[37]
	4	Charisma™ virtual social training: A digital health platform and protocol	[38]
	5	Development of a Social Communication Skills Intervention Using Video Modeling and Spherical Video-Based Virtual Reality for High Functioning Autism Spectrum Disorder Youth: A Preliminary Study	[39]
	6	"Can I be More Social with a Chatbot?": Social Connectedness Through Interactions of Autistic Adults with a Conversational Virtual Human	[40]
	7	Enhancing attention in autism spectrum disorder: comparative analysis of virtual reality-based training programs using physiological data	[41]
	8	Using virtual reality to enhance attention for autistic spectrum disorder with eye tracking	[42]
	9	Designing Gamified Virtual Reality Intervention Based on Experiential Learning to Enhance Social Reciprocity in Children with Autism Spectrum Disorder	[43]
	10	Learning experience design of verbal prompts in virtual reality-based training for autistic children	[44]
	11	Serious Game for VR Road Crossing in Special Needs Education	[45]

	12	Virtual Reality Air Travel Training with Children on the Autism Spectrum: A Preliminary Report	[46]
	13	FECTS: A Facial Emotion Cognition and Training System for Chinese Children with Autism Spectrum Disorder	[47]
	14	SoundFields: A virtual reality game designed to address auditory hypersensitivity in individuals with autism spectrum disorder	[48]
Theme 2: Assessment, Evaluation, and Multimodal Analytics in VR for Autism	15	Semi-Supervised Behavior Labeling Using Multimodal Data during Virtual Teamwork-Based Collaborative Activities	[49]
	16	Virtual Reality-Based Approach to Evaluate Emotional Everyday Scenarios for a Digital Health Application	[50]
	17	Applying multimodal data fusion to track autistic adolescents' representational flexibility development during virtual reality-based training	[51]
	18	On the Evaluation of Engagement in Immersive Applications When Users Are on the Autism Spectrum	[52]
	19	A Virtual Reality-Based System for the Screening and Classification of Autism	[53]
	20	ILAT (Software as a Service): Interactive Learning Application Tool for Autism Screening and Assessment in children with Autism Spectrum Disorder	[54]
	21	A Multimodal Framework for Integrating Motion Capture Monitoring into ASD Screening Utilizing XR Applications	[55]
	22	Individual Variability in Cognitive Engagement and Performance Adaptation During Virtual Reality Interaction: A Comparative EEG Study of Autistic and Neurotypical Individuals	[56]
Theme 3: Design, Framework, and Inclusive VR Systems for Autism	23	AutiSim: A Virtual Reality Simulation Game Based on the Autism Spectrum Disorder	[57]
	24	Law enforcement training using simulation for locally customized encounters	[58]
	25	"Someone who has ADHD or someone who has autism should make the Rules": A participatory study of neurodivergent Child perspectives on the ethics of Extended reality technologies	[59]
	26	Understanding experiences and interactions of children with Asperger's syndrome in Virtual Reality-based learning systems	[60]
	27	Inclusive Learning through Immersive Virtual Reality and Semantic Embodied Conversational Agent: A case study in children with autism	[61]
	28	Daily Life Adaptation in Autism: A Co-Design Framework for the Validation of Virtual Reality Experiential Training Systems	[62]
	29	Virtual Reality as a Tool for Children with Autism Spectrum Disorder	[63]

1) Theme 1: VR-based intervention and skill development for autism.

The results all point to a positive impact of VR-based interventions on cognitive, behavioural, and self-efficacy measures in people with autism, especially in cases of immersive and multimedia applications. The results in [35] indicate that there is an objectively observed change in self-efficacy and an increase in engagement during vocational training, indicating that the interactive settings can be used to boost confidence in performing tasks. Equally, [36], [43] note enhancement in cognitive, social communication and behavioural adaptation in structured VR learning situations, yet statistical significance is sensitive to sample size and design limitations. Additional findings [45], [46] indicate that VR simulation allows effective transfer of acquired skills to real-life situations, especially in everyday living activities like travel and road safety, which adds to the ecological validity of VR interventions.

There is also a high level of convergence in the outcomes of analyzing social communication and emotional development, whereby VR-based tools offer controlled but realistic practice environments. [38] note that structured virtual social training results in significant emotion recognition, social inferencing, and self-perception improvements, whereas [39] highlight that video modelling and spherical VR are particularly effective at understanding due to multi-perspective learning. Multiple studies reported that immersive and interactive VR systems improved emotional recognition and expression among autistic users [37], [47]. Moreover, [40] show that conversational virtual agents can facilitate perceived social connectedness, but anticipations of stronger interaction are not yet achieved, meaning that emotional realism and responsiveness continue to be developing issues in VR-based social systems.

Another prevalent finding of the studies reviewed is attention enhancement, especially when VR is used in combination with physiological monitoring and adaptive feedback processes. Several studies reported that reinforcement strategies and physiological monitoring enhanced attentional engagement within VR environments [41, 64]. [65] also indicates that thoughtfully created verbal cues in VR have the potential to affect the patterns of interaction and maintain the attention of users when performing training activities. These results are consistent with [48] in which exposure-based VR gaming minimized anxiety connected to auditory hypersensitivity, which indirectly underpins attentional stability. Taken together, these findings indicate that individual and modular VR processes are imperative in the treatment of attentional variability in autism.

Although the results are encouraging, some limitations and design aspects are consistently pointed out in research, which means that VR interventions should be refined further. Most research papers, such as [66], [67] have limitations of small sample size, limited intervention period, and limitations of generalization of results. Improved interactivity, user adaptability, and the integration of external support systems,

including parental involvement, are also highlighted in [39] and [65]. Moreover, [40] emphasizes the discrepancy between the expectations of the user and the technological possibilities of conversational systems. The overall findings of these observations demonstrate that, although VR-based interventions have great potential in improving the user experience and skill development of children with autism, future studies should focus on addressing scalability, long-term assessment, and user-related design aspects.

While the majority of studies demonstrated positive outcomes from VR-based interventions, the magnitude of effectiveness varied depending on immersion level, interaction modality, and participant characteristics. Studies utilizing adaptive and gamified VR systems generally demonstrated stronger improvements in social reciprocity and attentional engagement compared to static or less interactive environments. However, contradictions also emerged across the literature. For example, while immersive HMD-based systems increased engagement and realism, several studies simultaneously reported concerns regarding sensory overload and cybersickness among highly sensitive autistic users. Similarly, conversational virtual agents improved perceived social connectedness, yet emotional realism and natural responsiveness remained limited in more complex interactions. These findings suggest that VR effectiveness is not solely dependent on technological sophistication but rather on the extent to which the environment aligns with individual sensory and cognitive profiles.

2) Theme 2: Evaluation and multimodal analytics in VR for autism.

Multimodal data integration is an important technique to improve the accuracy and efficiency of behaviour recognition and evaluation in VR-based autism systems. Assessment, Evaluation, and Multimodal Analytics in VR on Autism report that semi-supervised learning can be a useful method to reduce the amount of manual annotation work but still achieve high prediction accuracy, which suggests that an efficient method to monitor behaviour in real-time is practical. Likewise, [68] demonstrate that using a combination of behavioural, physiological, and interaction data enhances predictive accuracy in monitoring cognitive skill development, especially representational flexibility. [69] also support the idea that the combination of subjective assessment with psychophysiological measures like ECG and EDA will enable the distinction between the complexity of a scenario in VR environments. All these results indicate that multimodal analytics is a more reliable and holistic representation of user states than single-source data solutions.

The other significant result pertains to the creation of objective and automated measures of autism screening and classification via VR technologies. [70] show that behavior monitoring in simulated social interactions is amenable to machine learning methods to differentiate between autistic and normal individuals with a high degree of accuracy, which proves the practicability of VR-based diagnostic devices. Also [54] emphasize the importance of integrated digital platforms, which are a combination of VR, artificial intelligence, and cloud-based systems that can aid early screening, behavioural monitoring, and intervention planning. Moreover, [55] note that to enhance the quality of behavioral information gathered during the assessment, it is crucial to have very accurate motion capture and full-body tracking in XR settings. Such systems are indications of a transition to more objective, data-driven approaches to lessening dependence on subjective clinical judgment.

The evaluation of the degree of involvement and mental responses in VR settings also emerges as a major point of interest in the findings. [71] demonstrate that immersive VR applications can potentially generate high engagement levels among autistic users, and the conventional evaluation measures may have to be redefined due to the unique behavioural aspects. Moreover, [56] reveal that cognitive engagement measured by EEG signals differs significantly based on certain individual factors such as IQ, familiarity with technologies, and pre-exposure to VR. [50] also, demonstrate the objectivity of emotional and physiological reactions in order to test the engagement of the user with varying levels of complexity in scenarios. These experiments lead to the fact that not all VR engagement is identical and that there ought to be adaptive evaluation models, which consider individual differences.

Regardless of these developments, various difficulties and constraints are always reported, especially with regard to standardisation, scalability, and personalisation of assessment models. According to [72] and [68], machine learning models demonstrate high performance, but their effectiveness is limited by the data quality and diversity, which are still limited on a small scale. [56] also emphasise that the variability between individuals makes it harder to generalise the results to other populations, and it requires more customised system design. Moreover, [71] emphasize the absence of agreement on assessment models that should be used with autistic users whereas [55] note the technical issues surrounding the necessary motion tracking.

The reviewed studies collectively demonstrate a transition from subjective observational assessment toward data-driven and multimodal evaluation frameworks. Nevertheless, important methodological differences remain evident across studies. While machine learning models achieved promising classification accuracy, performance was heavily dependent on data quality, sample diversity, and sensor reliability. Studies employing EEG, eye-tracking, and physiological monitoring reported stronger predictive capabilities, yet these approaches also introduced challenges related to equipment accessibility, calibration complexity, and scalability in real-world settings. Consequently, although multimodal analytics improve behavioral interpretation and personalization, the lack of standardized evaluation frameworks continues to limit comparability across VR autism studies.

3) Theme 3: Design, framework, and inclusive VR systems for autism.

The results indicate that the design of VR systems is becoming more oriented towards simulation-based practices to enhance awareness and insights into the experiences of autism. [56] show that immersive simulation games are also capable of capturing sensory sensitivities and social challenges, and usability tests show that the level of user comfort relating to simulator sickness is generally acceptable. On the same note,

[58] demonstrate that VR-based training environments offer realistic, but controlled practice environments, especially in the case of professional training such as law enforcement, where exposure to complex situations must be repeated. [73] also disclose that children with AS have been reported to develop an ability to adapt to virtual characters with time as they engage with VR learning systems, implying that well-thought-out virtual environments can elicit behavioral engagement in the long run. All these results suggest that the important design factors in VR systems that should be considered in autism-related uses include realism, immersion, and contextual relevance.

The other significant point that the findings raise is the focus on inclusive and assistive design to improve user experience and accessibility. According to [74], the combination of conversational agents and immersive VR systems leads to educational involvement as well as social integration, especially via natural language interaction. It is also pointed out in [75] that VR with virtual assistants has the potential to increase attention span and offer personalised assistance in everyday learning scenarios. Moreover, [76] reveal that co-design models with caregivers lead to system usability and user satisfaction and it is crucial to note that collaborative development processes are highly valued. All these studies suggest that inclusive VR systems must have adaptive communication and stakeholder engagement to ensure that children with autism engage in a significant manner.

Ethical considerations and participatory design is another valuable insight in the development of VR systems that can be used by neurodivergent users. [59] emphasize that children with autism insist that they are consulted into the design process and are concerned about the privacy of their data, overexposure, and potential misuse of immersive technologies. [58] indirectly support this line of thought and conclude that it is necessary to modify VR situations to its own user conditions to ensure relevance and acceptability. [57] also note the challenge of covering the experiences of autism in a manner that is not perpetuating stereotypes, which means that one has to be ethically mindful when developing content. Such findings reveal that technological innovation and the interests of users must be reconciled by adopting user-centred and ethically sound design practices.

In spite of such improvements, some limitations and design problems are always documented in research. According to [73] and [76], early pain and the necessity of a mentor are still obstacles to certain users, especially in their early exposure to VR systems. It is also noted by [75] that the variability in attention and engagement demands adaptive systems that can respond to the needs of individuals. In addition, [74] emphasize that even though promising results are demonstrated by immersive systems, the scalability and the effectiveness in the long run are under-researched. These results indicate that the design of VR systems in the future must focus more on flexibility, long-term usability analysis, and feedback mechanisms.

Across the reviewed literature, inclusive and participatory design consistently emerged as a critical factor influencing usability and long-term engagement. Studies involving caregivers, therapists, educators, and autistic users during development generally reported higher acceptance and improved interaction quality compared to systems developed without stakeholder collaboration. However, tensions remain between immersive realism and sensory comfort. While realistic VR simulations improved contextual learning and emotional engagement, excessive sensory stimulation occasionally reduced usability for participants with hypersensitivity. These findings indicate that future VR systems should prioritize adaptive sensory regulation and personalized interaction settings rather than relying solely on increased immersion.

IV. Discussion and Conclusion

The proposed systematic literature review is designed to explore the effectiveness of virtual reality (VR) technologies in enhancing the user experience among children with autism spectrum disorder through a synthesis of recent research published in 2020-2025.

The results indicate that there are a number of patterns that are common to the chosen studies. First, VR-based interventions have a high potential in enhancing social communication, cognitive skills, emotional recognition, and daily living skills in children with autism. These enhancements are more noticeable when immersive and interactive elements are integrated into structured learning environments. Second, the multimodal data system, including that based on behavioural, physiological, and interaction aspects, proves to be a valuable contribution to the field of user experience measurement. These approaches enable objective, real-time, and personalised assessment compared to conventional approaches. Third, the principles of user-centred and inclusive design are defined as the most important ones due to the enhanced engagement and usability. The adaptive sensory control, intuitive interaction techniques, co-design participation and ethical issues are some of the factors that are important in the development of positive user experiences. Artificial intelligence, along with real-time feedback systems, are also gaining popularity in the literature to enable personalisation and dynamic adaptation of VR systems.

The present review contributes to the area because it provides a methodical synthesis of a disjointed literature and brings all the various views together in three coherent themes: VR-based intervention and skill development, multimodal assessment and analytics, and inclusive design frameworks. This classification gives the review a more conceptual understanding of how the technological, behavioural and design aspects intersect to enhance user experience among children with autism. Furthermore, the review highlights a gradual shift from technology-centered approaches toward more human-centered, adaptive, and ethically conscious VR systems. The review also contributes to existing knowledge by emphasizing the importance of addressing sensory, emotional, and cognitive aspects of VR design rather than focusing solely on functional outcomes.

These findings have significant practical implications for different stakeholders. VR systems may serve as supportive tools in educational and clinical settings for skill training, behavioural therapy, and experiential learning, particularly for individuals with diverse sensory profiles. It is possible to add multimodal analytics that may assist practitioners in monitoring

progress in a more objective manner and developing personalised interventions. The findings are a reminder to the developers and designers that inclusive and user-centred design should be adopted, and VR applications must be made accessible, adaptable, and responsive to the diverse needs of autistic users.

Though these contributions are significant, several limitations remain evident across the reviewed studies. Most studies relied on relatively small participant groups, short intervention durations, and limited demographic diversity, reducing the generalizability of findings across broader autism populations. Future longitudinal research should therefore investigate the long-term effectiveness of VR interventions over periods ranging from six months to several years to better understand behavioral retention, emotional adaptation, and sustained engagement. For example, longitudinal studies conducted within schools or therapy centers could evaluate whether repeated VR-based social communication training contributes to measurable improvements in classroom interaction, emotional regulation, or independent living skills over time.

Future studies should also include more diverse participant groups across age ranges, cultural backgrounds, socioeconomic conditions, and autism support levels. Cross-cultural investigations are particularly important because sensory preferences, communication styles, educational practices, and caregiver expectations may differ significantly between countries and regions. For instance, VR learning environments developed for Western educational settings may require adaptation before implementation in Asian, Middle Eastern, or rural educational contexts where learning structures and technology accessibility differ substantially.

Another important direction involves the development of standardized evaluation frameworks for VR-based autism interventions. Current studies frequently employ different usability metrics, engagement scales, and physiological indicators, making direct comparison difficult. Future frameworks should integrate behavioral observation, eye-tracking, physiological monitoring, cognitive performance measures, and user satisfaction into unified assessment models. Such standardization would improve reproducibility and allow researchers to compare intervention outcomes across institutions and populations more effectively.

The integration of advanced technologies such as artificial intelligence, adaptive systems, and machine learning also presents promising opportunities for real-world implementation. AI-driven VR systems could dynamically adjust environmental complexity, sound intensity, visual stimulation, and task difficulty based on real-time behavioral and physiological responses from autistic users. In healthcare settings, clinicians may utilize adaptive VR systems for exposure therapy, emotional recognition training, or anxiety management. In educational environments, teachers could employ personalized VR simulations to support social interaction, classroom transition preparation, and vocational skill development. Similarly, organizations involved in workforce readiness or public services may adopt VR simulations to prepare autistic individuals for transportation use, workplace communication, or emergency response situations. Despite these opportunities, future implementation must also address ethical concerns related to privacy, data security, informed consent, and overdependence on immersive technologies. Participatory and user-centered design approaches should therefore remain central to future VR development to ensure that autistic individuals, caregivers, therapists, and educators actively contribute to system design and decision-making processes.

To conclude, this systematic review demonstrates the increased significance of virtual reality as a means of improving user experience in children with autism, but also reveals the important gaps that need to be addressed through future research. The integration of existing knowledge shows that the best VR systems should be based on technological innovations and user-centred design, multimodal assessment, and ethical considerations. Systematic reviews in this field play a critical role in systematising the rapidly growing body of knowledge, reducing fragmentation, and guiding future research directions. This type of evidence-based synthesis can not only advance theoretical knowledge but also support the development of more effective, inclusive, and sustainable VR solutions for individuals with autism.

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