

Extended Reality-Based Mobile Application Solutions for the Therapy of Children with Autism Spectrum Disorders: A Systematic Literature Review

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Submitted to: JMIR Serious Games
on: June 13, 2023

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Extended Reality-Based Mobile Application Solutions for the Therapy of Children with Autism Spectrum Disorders: A Systematic Literature Review

Marian-Vladut Toma¹ MSci; Cristina Elena Turcu² PhD; Corneliu Octavian Turcu² PhD; Sorin Vlad³ PhD; Doru Eugen Tiliute³ PhD; Paul Pascu³ PhD

¹Faculty of Electrical Engineering and Computer Science University of Suceava Suceava RO

²Faculty of Economics, Administration and Business "Stefan cel Mare" University of Suceava Suceava RO

Corresponding Author:

Marian-Vladut Toma MSci

Abstract

Background: Autism Spectrum Disorder (ASD) is a neurodevelopmental disability that is becoming increasingly prevalent, which has led to considerable research being focused on the therapy of individuals with autism, especially children, bearing in mind that early diagnosis and appropriate treatment can lead to an improvement in the condition. With the widespread availability of virtual/augmented/mixed reality (VR/AR/MR) technologies to the general public and the increasing popularity of mobile devices, there is a growing interest in the use of applications and technologies to provide support for the therapy of children with autism.

Objective: The objective of this study was to investigate the potential of virtual/ augmented/ mixed reality technologies in the context of therapy for children with autism spectrum disorder and to conduct a systematic review of the literature on the development of mobile applications based on these technologies.

Methods: For the systematic literature review, six research questions were defined in the first phase, after which five international databases (Web of Science, Scopus, Science Direct, IEEE Xplore Digital Library, and ACM Digital Library) were searched using specific search strings. Results were centralized, filtered, and processed, applying eligibility criteria and using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. The publications considered for the present study were carefully analyzed, and research questions were answered.

Results: In the first step, 179 publications found during the search were imported. After reviewing the title and abstract, a total of 89 publications were excluded because they did not address the proposed topic, focusing either on another condition or on other technologies. Next, for the analysis of the remaining 90 publications, the full text has been reviewed and the quality assessment criteria have been applied. The eligibility criteria were applied to 78 publications. After quality assessment, a total of 28 publications were considered in this study, in order to answer the research questions.

Conclusions: Although the concept of augmented/ virtual/ mixed reality is not exactly new, it has only recently begun to be used in the development of applications for the therapy of children with ASD. The findings reported in various publications indexed in five scientific databases highlighted the fact that these technologies are appropriate for this type of therapy, which motivates the in-depth study of this topic and the development of future applications based on these technologies.

Several studies show a distinct trend toward the use of augmented reality technology as an educational tool for people with ASD. This trend entails multidisciplinary cooperation and an integrated approach to research, with an emphasis on comprehensive empirical evaluations and technology ethics.

(JMIR Preprints 13/06/2023:49906)

DOI: <https://doi.org/10.2196/preprints.49906>

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Original Manuscript

First of all, we would like to express our sincere appreciation for the significant time and effort you have dedicated to improving our paper.

1) I did not find the author's response to the following question raised by reviewer X: "Has the review been registered, making the results accessible?"

Author response: We have responded to reviewer X's question regarding review registration and are sending you an excerpt of the response: Regarding reviewer X's comment, the suggestions are related to the need for such a review in the "Introduction" section and some additions in the "Discussions" section. Both matters were dealt with appropriately, with the mention that the review was not recorded, because at the time of the elaboration of the work we did not know that it was a necessity, but we will take it into account and we will certainly use this useful information.

2) Abstract: This section should be written according to the PRISMA guidelines for abstracts: <http://www.prisma-statement.org/extensions/Abstracts>

- Abstract: Authors should adjust the objective to be aligned with a systematic review objective. Please, considering rewording it as follows: "The objective of this study was to describe the literature on the potential of virtual/ augmented/ mixed reality technologies in the context of therapy for children with autism spectrum disorder".

Author response: Thank you for your valuable suggestion. We have carefully reviewed the PRISMA guidelines for abstracts and this has been adapted accordingly.

- Abstract: In the results section of the abstract, the authors are only describing how many studies were included in the systematic review, and a synthesis of the results is missing. Authors are recommended to describe the main findings of this systematic review (the answers for the research questions) in the results section.

Author response: The " Objectives " and " Results " sections have been revised according to the instructions received.

3) Introduction: The aim added at the end of the introduction needs to be slightly reworded to reflect the study design. Please, consider changing it to: "this systematic review aims to describe how these technologies can be used in the therapy of children with autism spectrum disorders."

Author response: Thank you very much for your suggestion to reword the aim of the study at the end of the introduction. We appreciate your feedback and we have made the necessary modifications.

4) Methods: PubMed should be searched.

Author response: Our study primarily focuses on the technical aspects of mobile application solutions using extended reality for autism therapy. To comprehensively cover our research domain, we chose to use multidisciplinary scientific databases, including Scopus, Science Direct, and Web of Science (WoS), along with two databases particularly relevant to computer science, namely, IEEE Xplore Digital Library and ACM Digital Library. We excluded other databases, such as PubMed, which are mainly related to biomedical and life sciences literature retrieval, as they did not align with the technical objective of our investigation.

5) PRISMA is a guideline and not a method. Please, make the necessary adjustments to the manuscript.

Author response: Necessary changes have been made to terms related to PRISMA guidelines.

6) Methods: Please, use the same subheadings proposed by the PRISMA guidelines (e.g., Eligibility criteria, Information sources, search strategy, selection process, etc.).

Author response: The subheadings have been renamed/adapted accordingly.

7) Methods: Authors stated the following: “For these sources, we have only considered publications that were relevant in computer science related categories, such as technology, engineering, and computer science, excluding categories related to medicine or chemistry.”. Please, clarify how and why this was done.

Author response: In this study, we focused on a technical approach to mobile application solutions that use extended reality for the therapy of children diagnosed with autism spectrum disorders. To ensure relevance, we applied filters to the search results across the considered five databases, with a specific emphasis on computer science-related domains. Categories related to medicine or chemistry were deliberately excluded from our study, as our research questions focus not only on the available applications but also on their technical details. Thus, we aimed to investigate the functionalities, technologies used, and the entire process of their development as part of our objectives.

8) Methods: Why did the authors limit the date of publication (after 2012)? This justification needs to be added to the manuscript.

Author response: The main focus of our research is on the technical aspects of mobile application solutions using extended reality for autism therapy. Over the last decade, there has been a significant advancement in the capabilities of mobile devices, as well as an increase in the widespread adoption of these devices. Consequently, the research on the development of mobile applications based on extended reality for therapeutic purposes was facilitated. Also, there was an increase in the use of these applications throughout the world. In light of these contextual factors, in this study, the scientific articles that were published after 2012 were considered.

9) Methods: This is one of the exclusion criteria: “The results with the topic focused on medicine, neurosciences, etc.”. This is not clear why the authors have this exclusion criteria.

Author response: The papers obtained through querying scientific databases have an interdisciplinary character. However, our study takes a technical and IT-focused approach to mobile application solutions using extended reality for autism therapy. Therefore, we needed to refine the results by considering inclusion/exclusion criteria. In line with our technical focus on mobile application solutions using extended reality for the therapy of children with ASD, we refined the search results across the five considered databases, prioritizing computer science-related domains. We deliberately excluded categories related to medicine, chemistry or neurosciences, as our research questions focus on both the available applications and their technical details.

11) Methods: The subheading “statistical analysis” is not referring to a statistical analysis, as this is describing the eligibility criteria instead. Please, adjust the subheading.

Author response: Following the PRISMA guidelines, the subheading "Statistical analysis" has been renamed "Eligibility criteria".

12) Study selection / screening process: Please, add the information about who performed the screening process. Was the screening process (assessing the eligibility of the studies by the title/abstract) performed by at least two independent raters? How about the screening of the full text?

Author response: To enable author collaboration, the data was imported into Google Sheets. Two reviewers (MVT and CET) conducted an independent screening of publications for inclusion based on title and abstract analysis. Studies meeting the eligibility criteria of both reviewers were then considered for full-text screening. Any disagreements were discussed face-to-face between the

reviewers, and a third party was involved to help reach unanimity where necessary. The same process was implemented for the full-text review, with the assistance of a third reviewer (SV).

13) How did the authors determine the quality of the studies? Did they use any standardized scale?

Author response: Given the nature of the research and its objectives, the 5 quality criteria that were developed specifically to achieve the goals of the research were used to evaluate the studies' quality by two authors. Each publication was carefully reviewed and assigned a score from 0 to 2, measuring the extent to which it corresponds to the quality assessment criteria and is the subject of this study (0=no, 1=partial, 2=yes). Thus, the maximum score for a paper could be 10. After that, the data was combined for further analysis using Microsoft Excel. After consolidation a score with a decimal part (e.g., 1.5) was rounded up to the nearest integer for better inclusion.

14) Methods: The information about the data extraction / data synthesis is missing in the methods section.

Author response: Following the PRISMA guidelines, a new section "Synthesis methods" has been added and the data synthesis process has been detailed:

The data extraction process was carried out to methodically address the stated research questions. Initially, a single reviewer handled the task of data extraction, leveraging the analytical capabilities of Microsoft Excel to facilitate a structured and organized approach to data collection and analysis. The same tool was used for data organization and representation. Within this application, a comprehensive table was constructed where the rows were designated to the considered references, and corresponding data to individual research questions were entered into separate columns, fostering a systematic representation of the data acquired. Subsequently, to enhance the reliability and validity of the data integration process, a second reviewer performed a verification of the initially extracted data. This encompassing procedure ensured a high degree of accuracy and reduced potential discrepancies, thus ensuring the integrity of the data.

15) Results: Please, note that some figures are too simple (e.g., figures 5 and 7), and should be replaced with a table or a paragraph in the text, as advised in the following link: <https://support.jmir.org/hc/en-us/articles/360013033312-What-types-of-figures-are-not-permitted-in-JMIR-articles->

Author response: We appreciate your insightful recommendation. We have implemented the change that you suggested, and we have substituted paragraph explanations for figures 5 and 7.

16) Please address the following sections, if not done already: (statements after Discussion section)

- Acknowledgments - See online information: <https://support.jmir.org/hc/en-us/articles/360015982471-How-should-the-Acknowledgments-section-be-formatted->

- Funding Statement - If applicable, add a funding statement. See the link above for more information.

- Data Availability - Please add a section on Data Availability. -- We encourage authors to ensure that their data sets are either deposited in publicly available repositories (where available and appropriate) or presented in the main manuscript or additional supporting files whenever possible. For example, these can be added as a URL to a repository and a URL to code used, attached as a Multimedia Appendix, or submitted/published separately in JMIR Data (<https://data.jmir.org/>). A Data Availability statement should still be provided even if access is restricted. In this case, a reason should be provided and possible steps for requesting access could be provided. For example statements which may be applicable to your data type(s) and study design, visit: <https://support.jmir.org/hc/en-us/articles/360030832631-What-is-your-data-sharing-policy->

- Conflict of Interest - Please ensure you have reviewed JMIR's online information regarding COI

disclosures and included them accordingly in the manuscript in the appropriate section. <https://support.jmir.org/hc/en-us/articles/115001252671-How-does-JMIR-define-a-Conflict-of-Interest-COI->

- Author Contributions - Please add a statement of Author Contributions according to the CRediT taxonomy. <https://credit.niso.org/>

- Please disclose whether generative AI was used in any portion of the manuscript writing. <https://support.jmir.org/hc/en-us/articles/13387268671771-Do-you-allow-the-the-use-of-ChatGPT-or-other-generative-language-models-and-how-should-this-be-reported->

Author response: Acknowledgments: This research was funded by the project “119722/Centru pentru transferul de cunoștințe către întreprinderi din domeniul ICT—CENTRIC, Contract subsidiar 22080/05.10.2022/Autism/ASSIST, Autism ASSISTant - Asistent virtual pentru dezvoltarea abilităților cognitive ale copiilor cu patologie de spectru autist”, contract no. 5/AXA 1/1.2.3/G/13.06.2018, cod SMIS 2014+ 119722 (ID P_40_305).

Funding Statement: Non applicable.

Data Availability: As far as the availability of data is concerned, it has been included in the manuscript through Multimedia Appendix 1, which was uploaded at the same time as supplementary material on the JMIR authors' platform.

Conflicts of Interest: None declared

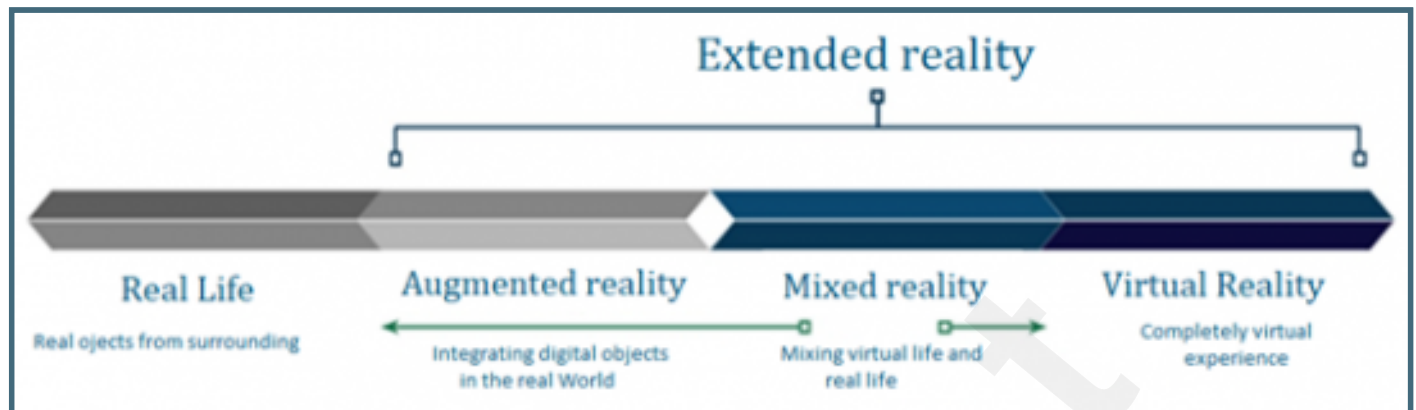
- Author Contributions: MVT and CET were involved in the concept and design of the review. All authors made substantial contributions to the analysis, preparation, interpretation, and organization of the data. The final manuscript was read, revised, and approved by all authors.

Please disclose whether generative AI was used in any portion of the manuscript writing: The authors attest that there was no use of generative artificial intelligence (AI) technology in the generation of text, figures, or other informational content of this manuscript.

Supplementary Files

Figures

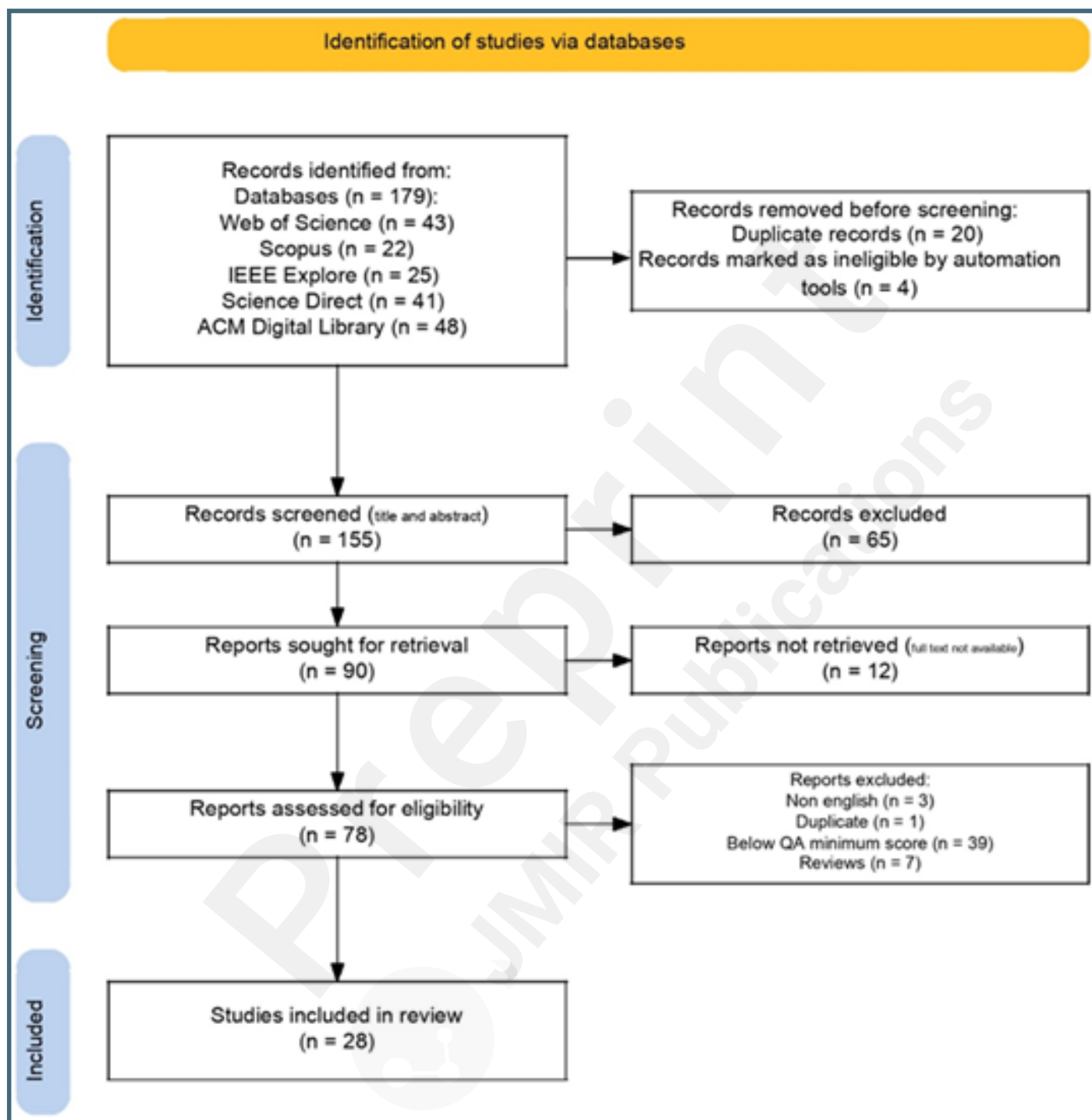
The extended reality concept [19].



Paper's quality assessment.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	No.	Item Type	Contribution or review	Publication Year	Author	Title	Publication Title	Abstract Note	QC1	QC2	QC3	QC4	QC5	Total
2	1	journalArticle	review	2021	Lian, Xiaojie; Sunar, F	Mobile Augment	APPLIED SCIEN	Over the past decade, e	2	2	2	2	2	10
3	2	journalArticle	contribution	2022	Lopez-Belmonte, Jes	The Impact of Ge	EDUCATION IN	Today's education is in	2	2	0	0	1	5
4	3	conferencePaper	contribution	2016	Gea, M.; Allaman, X.;	TOWARDS SMAR	EDULEARN16:	Smart city is a promisin	1	1	1	0	1	4
5	4	conferencePaper	contribution	2013	Vullamparthi, Annie	Assistive Learnin	2013 IEEE FIFTH	Innovative computer ai	2	2	2	2	2	10
6	5	journalArticle	review	2020	Baragash, Reem Sula	Augmented real	EUROPEAN JOU	There is a growing inter	1	1	1	1	1	5
7	6	journalArticle	contribution		Glaser, Noah; Newbu	Video-Based Viri	TECHNOLOGY	Research suggests that	2	0	2	1	1	6
8	7	conferencePaper	contribution	2020	Bouaziz, Rahma; Alh	Using Marker Bas	2020 IEEE INTE	Autistic children suffer	2	2	2	2	2	10
9	8	conferencePaper	contribution	2017	Pradibta, Hendra; W	Designing AR Da	2017 INTERNAT	An Individual with Auti	2	2	2	2	1	9
10	9	journalArticle	contribution	2019	Abou El-Seoud, M. S	Assisting Individ	INTERNATIONA	Individuals with autism	2	2	2	2	2	10
11	10	journalArticle	contribution	2022	Hashim, Haida Umier	"AReal-Vocab": A	SUSTAINABILI	The American Psychiatr	2	2	2	2	2	10
12	11	conferencePaper	contribution	2018	Pradibta, Hendra; W	The evaluation o	3RD ANNUAL	ARdox is Mobile Augme	0	0	0	0	0	0
13	12	journalArticle	contribution	2022	Wan, Guobin; Deng,	FACTS: A Facial E	COMPUTATION	Traditional training me	2	2	0	1	2	7
14	13	conferencePaper	contribution	2015	Nubia, Rincon M.; Fa	Development of	2015 WORKSH	An augmented reality r	2	2	2	2	2	10
15	14	conferencePaper	contribution	2020	Wang, Katherine; Zh	Using Mobile Au	CHI'20: EXTEN	Adults on the autism sp	2	0	2	2	2	8
16	15	conferencePaper	contribution	2019	Tang, Tiffany Y.; Xu, J	Automatic Objec	3RD INTERNAT	A number of previous c	2	2	2	2	2	10
17	16	journalArticle	contribution	2021	Hashim, Haida Umier	Augmented Real	ARAB WORLD	American Psychiatric A	0	0	0	0	0	0
18	17	conferencePaper	contribution	2021	Kavitha, V; Mohan, A	Immersive Learn	ICSPC'21: 2021	Autism Spectrum Disor	2	2	2	2	2	10
19	18	journalArticle	review	2018	Johnston, Daniel; Eg	Innovative comp	COGENT PSYC	Individuals with autism	2	2	0	0	1	5
20	19	journalArticle	review	2019	Putnam, Cynthia; Ha	Interactive Tech	ACM TRANSAC	Autism spectrum disor	2	2	0	1	1	6
21	20	journalArticle	review		Mukherjee, Debarati	Digital tools for	AUTISM	Current challenges in e	2	0	1	1	0	4
22	21	journalArticle	review	2020	Valentine, Althea Z.	A systematic rev	CLINICAL PSYC	Technology-based inte	1	2	2	2	1	8
23	22	conferencePaper	contribution	2022	T, Nithya Shree; Selv	An Interactive N	2022 Internati	Autism in children is ch	2	2	2	2	2	10
24	23	conferencePaper	review	2019	Khowaja, Kamran; Al	Use of augments	2019 IEEE 6th	The purpose of this rev	2	2	2	1	2	9
25	24	conferencePaper	review	2020	Almurashi, Hanin A.	Augmented Real	2020 IEEE Inter	Currently, augmented r	2	1	1	1	1	6
26	25	conferencePaper	contribution	2020	Xia, Mengting; Chen,	ParaShop: A Mob	2020 IEEE MIT	Approximately 1 in 160	2	2	2	2	2	10
27	26	conferencePaper	contribution	2017	Silva, Salatiel Dantas	Knowledgeemon	2017 19th Sym	Autism Spectrum Disor	2	2	2	2	1	9
28	27	journalArticle	review	2021	Farzana, Wallia; Sar	Technological Ev	IEEE Access	Augmentative and Alte	2	2	1	2	2	9
29	28	conferencePaper	contribution	2021	Gulati, Rishi; Handa,	Towards Develop	2021 Third Inte	Children suffering from	2	2	2	0	1	7
30	29	journalArticle	contribution	2014	Escobedo, Lizbeth; T	Using Augmente	IEEE Pervasive	Children with autism h	2	2	2	2	2	10
31	30	conferencePaper	contribution	2022	Romadion Junaedi, A	Usability Testing	2022 2nd Inter	The development of co	2	2	2	0	0	6
32	31	conferencePaper	contribution	2019	Machado, Eduardo; C	An Assistive Aug	2019 IEEE Intl	Acquiring daily living sk	2	2	2	2	2	10

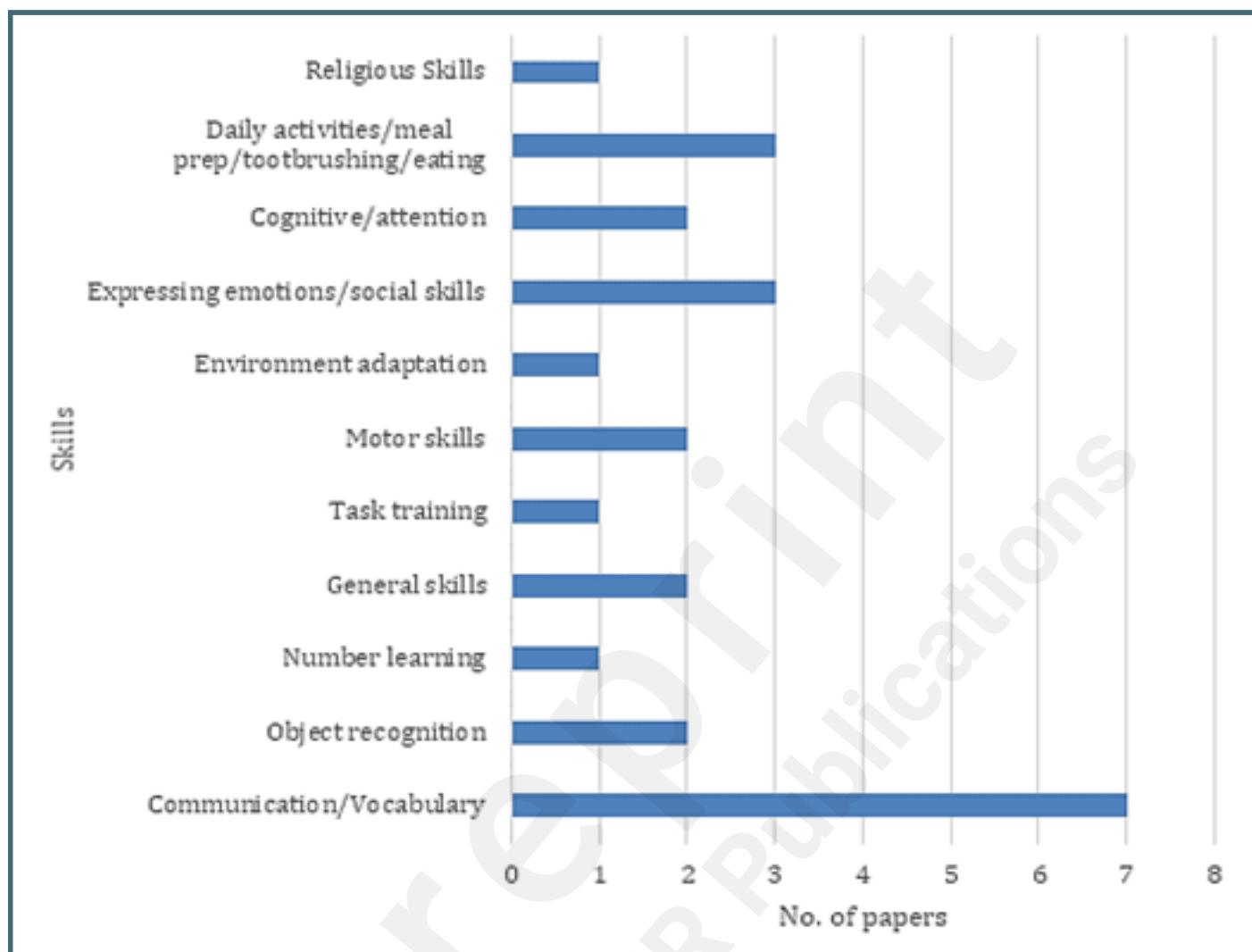
The PRISMA flow diagram.



Time distribution of reviewed publications.



Aimed learning skills.



Multimedia Appendixes

Paper's quality assessment.

URL: <http://asset.jmir.pub/assets/de964929d895277f70e826be6ead6a17.xls>



CONSORT (or other) checklists

Prisma 2020 checklist.

URL: <http://asset.jmir.pub/assets/a98ccb2e0d001a97deb1b57fb133e0ce.pdf>