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Systematic Review of Extended Reality Digital Therapy for Enhancing Mental Health Among South Korean Adolescents and Young Adults

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Digital therapy using extended reality (XR) holds great promise for addressing the mental health needs of adolescents and young adults. This study addresses a notable research gap in South Korea by systematically reviewing XR-based digital therapy for the mental health of South Korean adolescents and young adults. We analyzed 26 studies encompassing various aspects, including study type, publication date, research field, research methodology, data sources, program types, program content, sample characteristics, target population, assessment tools, and program effectiveness. Notably, 46.15% of the studies employed an experimental design, whereas over 53% utilized non-experimental approaches. Experimental studies lacked a genuine design, standardized questionnaires, and control variables. Similarly, non-experimental studies failed to report specific literature selection criteria. Consequently, future studies should adopt rigorous methodologies to enhance reliability and validity. Moreover, over 85% of the 26 studies focused solely on virtual reality and did not incorporate augmented or mixed reality. This study identifies the limitations of the previous research. These findings emphasize the need for structured investigations to advance the development of XR-based digital therapy to promote mental health in adolescents and young adults in South Korea.

Keywords: Virtual reality; Augmented reality; Mixed reality; Mental health; Adolescents; Young adults; South Korea.

INTRODUCTION

In recent years, with coronavirus disease 2019, information and communication technology (ICT) in healthcare has gained attention, shifting the focus from hospital-centered services to patient- and consumer-centered services [1,2]. Research exemplifies digital therapeutics (DTx) as a form of healthcare integrating ICT, defined as "Software as a Medical Device" that provides evidence-based therapeutic interventions to patients to prevent, manage, and treat medical disorders or diseases [3]. DTx has been applied to various medical conditions, including neuropsychiatric disorders, such as drug addiction, sleep disorders, schizophrenia, attention-deficit/hyperactivity disorder (ADHD), depression, and dementia [4-6].

While medical services primarily provide DTx, mental health professionals such as psychotherapists also report digital interventions utilizing ICT and various psychotherapies such as cognitive behavioral therapy (CBT) [7,8]. In par-

ticular, their effectiveness in reducing anxiety and depression [8], improving social skills in autism spectrum disorder [7], and addressing demographic and cultural differences, as well as spatial barriers [8], is appealing to many mental health professionals. Digital therapies, including DTx, are typically delivered through mobile apps or products that apply or include technologies such as virtual reality (VR) and artificial intelligence [7,9].

One technology gaining attention is VR, which applies physical-world realization to provide a highly immersive experience through devices such as head-mounted displays (HMDs) [10,11]. Recently, researchers have used the term extended reality (XR) to encompass VR, augmented reality (AR), and mixed reality (MR) technologies [12,13]. Upon closer examination of AR, VR, and MR [14], AR superimposes digital content on the physical world using a medium that simultaneously presents the real world and digital content, enabling users to experience and engage with both realities concurrently. VR allows users to interact with and immerse themselves in a computer-generated environment, experiencing a fully immersive sensory reception created solely by vari-

ous hardware and simulated elements. However, MR combines the characteristics of VR and AR to yield a hybrid form of XR. According to Shin et al. [10], XR technology is highly therapeutic as it can enhance cognition through audio-visual and tactile experiences, resulting in a heightened sense of immersion.

Adolescence is a particularly vulnerable period for mental health problems, primarily depression, anxiety, and ADHD [15]. Young adults have also experienced an increased prevalence of depression, anxiety, and suicide during the pandemic [16]. Between 2016 and 2020, there was an increase in the number of adolescents treated for mental illness [17]. Similarly, from 2015 to 2019, the number of adolescents who committed suicide and self-inflicted suicide attempts rose [17]. Furthermore, researchers have found an association between the negative impact on household economies caused by the pandemic and heightened anxiety, stress, depression, and even thoughts of suicide among adolescents [18-20]. Therefore, the timely identification and implementation of suitable interventions are of the utmost significance in mitigating long-term consequences and promoting well-being. There is growing anticipation among numerous experts that XR will demonstrate enhanced efficacy, specifically for adolescents and young adults [12,21] since XR's optimization overcomes time and place limitations and immerses in therapeutic interventions. Furthermore, the present generation of adolescents and young adults exhibits unprecedented familiarity with digital devices. They can easily accept them without resisting or rejecting XR for mental health [22,23].

However, systematic literature reviews focusing on XR for the mental health of adolescents and young adults are lacking. This knowledge gap presents challenges in understanding research trends in South Korea. Thus, the present study addresses this issue by systematically reviewing the literature on digital therapies for adolescent mental health in South Korea. Specifically, this review focuses on digital treatments that utilize XR. Moreover, this study defines mental health as a mental illness encompassing psychosocial crises [24]. Therefore, the scope of this study covers mental illnesses, such as ADHD, addiction, depression, anxiety disorders, and psychosocial conditions, including social adaptation and stress.

METHODS

Search strategy

We systematically searched four prominent and extensively used databases in South Korea: KISS, RISS, DBpia, and KCI [25,26]. The search encompassed all records up to January 2023. The search terms comprised three sets of topic keywords: 1) extended reality, virtual reality, augmented reality, and mixed reality; 2) mental health, depression, anxiety, stress, addiction, ADHD, psychotherapy, emotion, and social adaptation; and 3) adolescent, youth, teenagers, students, and university students.

Study selection

The present study adhered to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines and encompassed four stages: identification, screening, eligibility, and inclusion [27]. Initially, we imported a comprehensive collection of 2930 references from each database, eliminating 1594 duplicate entries and leaving 1336 records for the title and abstract screening phases. Three reviewers independently assessed each article and assigned a rating of "yes" or "no." In the event of rating discrepancies, the authors engaged in discussions to reach a consensus. In the initial screening stage, 1298 irrelevant records were excluded, resulting in 38 articles progressing to the full-text review stage. After applying the National Institutes of Health (NIH) quality assessment criteria, we excluded another 12 articles, leaving 26 for the final analysis (Fig. 1).

This systematic review included studies that satisfied the inclusion and exclusion criteria. To be included, studies had to meet the following conditions: 1) peer-reviewed articles, master's theses, doctoral dissertations, or conference proceedings; 2) original articles, case reports, review articles, or editorials; 3) published in South Korea; 4) information on digital therapies utilizing XR for the enhancement of mental health in adolescents and young adults in South Korea; 5) samples consisting of adolescents and young adults; and 6) a "fair" or "good" rating based on the NIH quality assessment tool [28], as determined by all three reviewers.

We excluded studies if they met at least one of the following criteria: 1) conducted outside the South Korean setting, 2) lacked information related to digital therapies employing XR for the improvement of mental health in South Korean adolescents and young adults, 3) targeted middle-aged and older adults, and 4) received a rating of "poor" according to the NIH quality assessment tool [28], as determined by all three reviewers.

Data extraction and analysis

Before commencing the coding procedure, the three reviewers implemented a random selection process involving two of the 26 studies for double-screening purposes to ensure consistency among the raters [29]. The reviewers assessed the inter-rater reliability using Fleiss's kappa coefficient, which yielded almost perfect agreement, with a value of 0.862 [30]. Three reviewers independently assessed and coded the articles using Excel spreadsheet matrices.
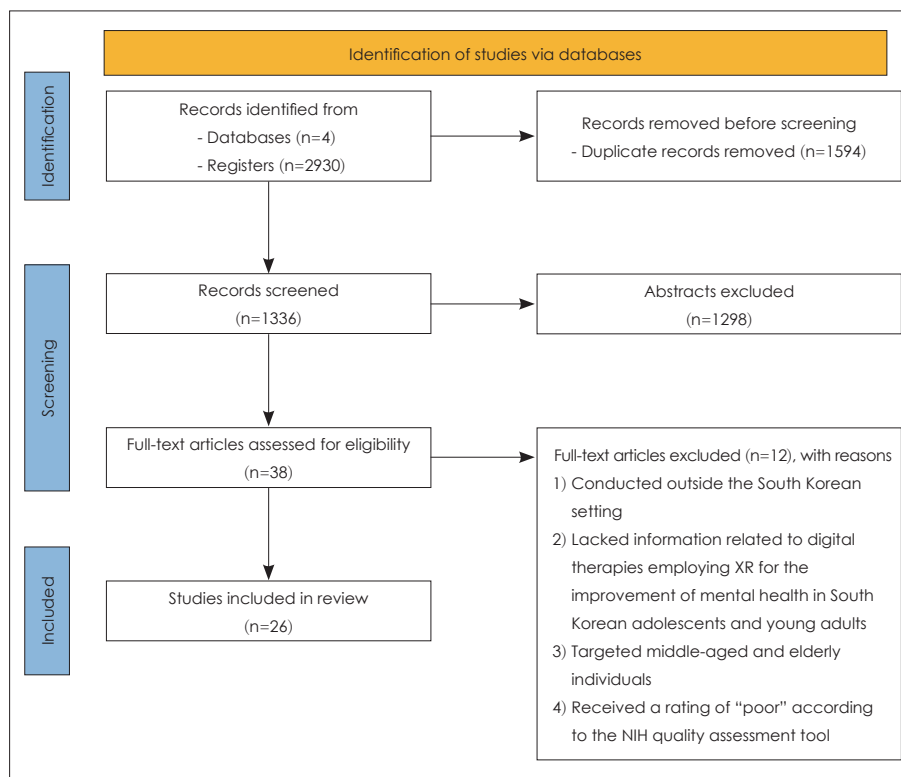
Fig. 1. Selection procedure flow chart. XR, extended reality; NIH, National Institutes of Health.

The coding process encompassed various components, including the author and year, research field, study type, research method, data source, target variable, and sample characteristics, including sample size, age range, mean age, percentage distribution by gender, type of program, number of sessions, program contents, program development process, XR technique development process, measurement tools utilized for assessment, main findings or outcomes (i.e., the effectiveness of the program), and adjustment considerations. The coding results are presented in Table 1 [9,31-41] and Table 2 [22,23,42-53].

RESULTS

Study type
A total of 26 studies met our inclusion criteria. Noteworthy, of these 26 studies, 12 (46.15%) focused on experimental research. Specifically, they aimed to develop digital therapies utilizing XR technology to address mental health issues among adolescents in South Korea while also assessing the effectiveness of such treatments.

The remaining 14 studies (53.85%) were non-experimental. These exploratory studies based on literature reviews examined the applicability of XR technology or provided a model for developing programs for adolescent and young

adults' mental health using XR technology. Among all non-experimental studies, we classified the study types into two groups: exploratory studies in literature reviews (n=8) and program development studies (n=6), which specifically presented a program model and system.

Date of publication
As shown in Fig. 2, all the studies in this analysis were conducted between 2003 and 2022. Consistent yearly publications have been made since 2015, with a peaked rate in 2020. Remarkably, papers published in 2019 and 2020 constituted 50% (6 out of 12) of all the experimental studies. Conversely, non-experimental studies were primarily conducted in 2020 and 2022, representing 64.28% (9 out of 14).

Research field
The present study established a wide array of research domains related to utilizing XR-based digital therapies to enhance adolescents' mental well-being in South Korea. These domains include psychology, computer science, game-mobile, social welfare, design and media, public administration, correctional counseling education, and biomedical engineering. Notably, six studies (50%) were predominantly grounded in psychology within the subset of experimental studies. Furthermore, it is particularly intriguing to observe that nu-

Table 1. Experimental studies

Study	Research field	Research method	Target variable	Sample (size; age; gender)	Program contents/ number of sessions	Measurement tool used to assess	Effectiveness of the program
Lee et al. (2003) [31]	Convergence (biomedical engineering, youth studies)	Pretest–posttest control group design	Nicotine dependency	n=22; 17–24 yrs (mean=22.2); 100% male	- Virtual bar - 1 session	7 questions from Fagerstrom Tolerance Questionnaire Visual Analogue Scale	Significantly effective
Kim et al. (2006) [32]	Convergence (social welfare, child welfare, design & media, psychology)	Pretest–posttest control group design	Sociality	n=34; 5–8 yrs	- A 3 themes sociality development program - 5 sessions	Lowa Social Competence Scales (Preschool form), KEDI-WISC (coding test, social maturity scale)	Significantly effective
Lee (2016) [33]	Media	One-shot case study	Social adaptability & Task performance behavior	n=6; 50% male	- Bus commute VR program - 1 session	Reconstructed the smart class observation checklist	Effective (no statistical examination)
Kim (2017) [34]	Psychology	Pretest–posttest control group design	Test anxiety	n=20; 16 yrs; 65% male	- Exposure to test conditions - 4 sessions	TAI-K, Pulse (fingertip pulse oximeter), VAS	Significantly effective (partially)
Kim et al. (2017) [35]	Psychology	Pretest–posttest control group design	Public speaking anxiety	n=48; university students; 100% female	- Perform presentations in virtual reality - 4 sessions	SAS, SATI, Predicted/Peak/Ending Anxiety, TBCL for Performance Anxiety, fingertip pulse oximeter	Significantly effective
Bang et al. (2019) [36]	Psychology	Pretest–posttest control group design	Public speaking anxiety & Self-focused attention	n=65; university students; 100% female	- Perform presentation in a realistic classroom situation - 4 sessions	K-SAS, K-SATI, SDSAS, Predicted/Peak/Ending Anxiety, TBCL, Fingertip Pulse Oximeter	Significantly effective
Jung and Oh (2019) [37]	Special education	One-shot case study	Community adaptation skills	n=6; elementary students; 67% male	- Storytelling, mixing reality, application, robot coding, peer tutoring - 3 sessions	Evaluation question	Effective (no statistical examination)
Yoon et al. (2019) [38]	Convergence (psychology, computer science, game-mobile)	Pretest–posttest control group design	Social anxiety level	n=22; college students; 86.36% female	- Poetry reading, positive/negative feedback, perform an unpracticed presentation - 4 sessions	SADS, LSAS, SST, SUDS, HR Measurement	Significantly effective
Jin and Kim (2020) [39]	Convergence (medical administration, psychotherapy, public administration)	Pretest–posttest control group design	Academic stress & Test anxiety	n=60; 18 yrs; 100% male	- 6 main images - 3 sessions	SAS, TAI	Significantly effective
Kim et al. (2020) [40]	Psychology	Pretest–posttest control group design	Heterosocial anxiety	n=35; university students; 100% female	- Chatting with Avatar - 4 sessions	SISST, the Subjective Unit of Discomfort Scale, the heart rate, TBCL	Significantly effective
Hong et al. (2020) [41]	Convergence (behavioral science, medical science, neurology, psychiatry)	One-group pretest–posttest design	Improvement of anger-control	n=32; mean=12.5 yrs; 40.6% male	- Virtual reality (VR)-based anger control training with two tasks - 1 session	CBCL 6–18, VAS	Significantly effective
Son et al. (2022) [9]	Convergence (software, computer science)	One-shot case study	ADHD core symptom severity	n=304; 5–12 yrs; 50% male	- 6 VR missions - 1 session	DSM-5	Significantly effective

ADHD, attention-deficit/hyperactivity disorder; CBCL, Child Behavior Checklist; DSM-5, Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; KEDI-WISC, Korean Educational Development Institute-Wechsler Intelligence Scale for Children; K-SAS, Korean version of Speech Anxiety Scale; K-SATI, Korean version of the Speech Anxiety Thoughts Inventory; LSAS, Liebowitz Social Anxiety Scale; SADS, Social Avoidance and Distress Scale; SAS, Speech Anxiety Scale; SATI, Speech Anxiety Thoughts Inventory; SDSAS, Scale for Dispositional Self-Focused Attention in Social situation; SISST, Social Interaction Self-Statement Test; SST, Scrambled Sentence completion Task; SUDS, Subjective Unit of Discomfort Scale; TAI-K, Test Anxiety Inventory-Korea; TBCL, Timed Behavior Checklist for Performance Anxiety; VAS, visual analog scale

Table 2. Non-experimental studies

Study	Research field	Study type	Data source	Target variable	Literature selection criteria	Program contents/ number of sessions	Main findings/outcomes
Ryu and Yeon (2015) [42]	Convergence	Program development	Previous VR-CBT programs	Anger management for juvenile offenders	N.A	Total of 3 session 1. Understanding self-anger 2. Unmet needs and emotions 3. Automatic thinking and irrational beliefs	Present VR anger management program
Kim et al. (2017) [43]	Convergence	Program development	Literature	Trauma in multi-cultural adolescent	N.A	N.A	Present 3 elements for VR-CBT Program Model
Rhee (2018) [44]	Art therapy	Program development	Survey analysis	Career stress	N.A	4 of 12 sessions using VR (360 VR - reduce stress through images)	Present VR program for career stress
Ryu (2018) [45]	Criminal psychology	Exploratory	Literature	Anger management for ADHD	N.A	1. Eliminating maladaptive behavior 2. Cognitive restructuring 3. Self-anger management 4. 5. Stress, Pain, Frustration Tolerance 6. Self-compassion training 7. Mindfulness-Based Stress Reduction	Exploring the applicability of Integrative Anger Management Virtual Reality Therapy
Ryu and Han (2019) [22]	Digital culture & contents	Exploratory	Literature	Advantages and disadvantages of VR application tools	N.A	N.A	Exploring the applicability of VR technology in mental health
Huh et al. (2020) [46]	Kinesiology	Program development	112 games, previous games research	Physical activity to improve game overindulgence	Presented	Total of 12 sessions (The complex composition of physical activities)	Present physical activity VR gamification model
Kim (2020) [47]	Media design	Program development	Movie	Extended reality therapy for PTSD	N.A	No session presented (Identification with, projection, and memory reprocessing through movie character)	Present the model for applying Cinematherapy to XR
Lee (2020) [48]	Social welfare	Exploratory	Literature	Improvement adjustment and problems in the military	N.A	N.A	Exploring VR applicability
Ko and Lee (2021) [49]	Convergence	Exploratory	Literature	The essential elements of VR dance/movement therapy for adolescents' mental health	Presented	N.A	Exploring VR applicability
Lee (2021) [50]	Social welfare	Exploratory	Literature	Improvement of adjustment and the problem in a youth shelter	N.A	N.A	Exploring VR applicability
Ryu (2021) [51]	Computer science and engineering	Program development	Literature	Development of ADHD Diagnostic VR System	N.A	No session presented (Using VR games as ADHD diagnostic system)	Development ADHD diagnostic system
Kim and Kim (2022) [52]	Film, digital media & communication	Exploratory	Literature	Relief of preoperative anxiety in children	Presented	N.A	Exploring the effect of relieving anxiety as a digital stabilizer
Ryu (2022) [53]	Education of correctional counseling	Exploratory	Literature	ADHD, Conduct Disorder (CD)	N.A	N.A	Exploring VR-CBT programs for ADHD and CD
You (2022) [23]	Police & law	Exploratory	Literature	Prevention and reduction of school violence	N.A	N.A	Exploring applicability to prevent and reduce school violence using AR/VR programs

ADHD, attention-deficit/hyperactivity disorder; AR, augmented reality; N.A, not applicable; PTSD, post-traumatic stress disorder; VR, virtual reality; VR-CBT, virtual reality–cognitive behavioral therapy; XR, extended reality
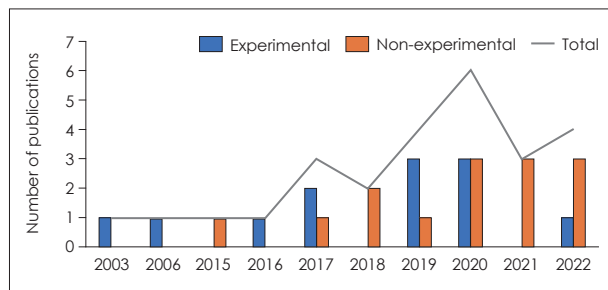
Fig. 2. Publication trends by year. Years with no publications are not shown.

merous studies were not confined to a single disciplinary framework but emerged as convergence studies that amalgamated insights from diverse fields. We characterized six studies (50%) as convergence studies that embraced the expertise of multiple research disciplines. For instance, Yoon et al. [38] conducted a convergence study that integrated psychology, computer science, and mobile game research [38].

The non-experimental studies included three in culture and content, communication, and media [22,47,52], two in social welfare [48,50], and three in convergence fields [42,43,49]. Within convergence studies, Kim et al.'s research [43] is a multidisciplinary investigation that integrates nursing, computer science, and child welfare. Similarly, Ko and Lee [49] represented an interdisciplinary exploration encompassing creative art psychotherapy and counseling psychology. In addition, we identified a single study in criminal psychology [45], correctional counseling [53], computer science [51], art therapy [44], police and law [23], and kinesiology [46].

Research method and data source

Regarding the research methodology of the 12 experimental studies, most (n=8, 66.67%) utilized a pretest–posttest control group design, indicating its prevalence in over half of the investigations. Furthermore, three studies (25%) adopted a one-shot case-study design, while one (8.33%) employed a one-group pretest–posttest design. Notably, all 12 studies (100%) implemented interventions utilizing the developed XR programs, accompanied by surveys designed to assess the effectiveness of these programs.

All eight (57.14%) of the 14 non-experimental studies used literature review methods. However, only two of the eight articles (25%) reported the criteria for literature selection [49,52], and the remaining six (75%) did not provide relevant criteria. The specificities of the literature selection criteria varied. For example, Kim and Kim [52] offered specific criteria, such as emotion-related studies of children aged 3–11 years and children's hospital cases selected by Newsweek and the U.S. News. However, Ko and Lee [49] were not specific, stating only "studies related to art therapy and VR." Three

non-experimental program development studies reported the literature as a data source without literature selection criteria [43,47,51]. Other data sources include surveys [44], analyses of existing sports games and game trends over the past decade [46], and previous VR-CBT programs [42].

Types of programs

All programs exclusively utilized VR technology within the subset of experimental studies, without including AR or MR technology. Among the 12 studies examined, 10 (83.33%) provided detailed information on the development process of their VR programs. Seven of the 10 studies (70%) reported using Unity's game engine software. VR programs employ a diverse range of technologies, including headphones, Pentium IV computers, OpenGL Accelerator VGA Cards, HMDs, sensor VR maps, robot coding data, community trip applications, mobile applications, responsive web design, Android applications, and Samsung Galaxy Gear VR.

The sessions in the 12 VR programs varied from 1 to 10. The mean number of sessions was 3.33 (standard deviation [SD]=2.39). Notably, four sessions were the most frequently observed session type employed in five studies (41.67%). Subsequently, we found one session (n=4, 33.33%) and three sessions (n=2, 16.67%). Additionally, one study (8.33%) utilized 5–10 sessions. Among the 12 studies examined, only two (16.67%) provided information regarding the duration of each session. All reported session durations were consistent at 30 minutes.

Of the 14 non-experimental studies, 10 focused exclusively on VR content. Four out of 14 non-experimental studies also presented the program's specific session structure and contents [42,44-46]. Rhee [44] and Huh et al. [46] divided the program into 12 sessions. While Rhee's [44] program is a partial application of VR in only four sessions of the art therapy program, Huh et al. [45] comprised 12 sessions of 40 min each and presented physical activity games through VR in all sessions. Ryu and Yeon [42] proposed a three-session anger management program using VR with subtopics in the VR content for each session. The duration of VR content varied from 10 to 35 min for each subtopic. Conversely, Ryu [45] presented seven treatment contents based on CBT that one could use in an integrated and complementary approach as "Integrative Anger Management Virtual Reality Therapy," but did not provide the specific number and time of each session.

Contents of program

Of the 12 experimental studies, the VR program content exhibited considerable diversity based on the specific program. One particular type of program was the VR exposure program, which was the focus of six studies [31,34-36,38,40].

Research endeavors targeting anxiety commonly employ such programs, exposing participants to virtual tests or presentation scenarios. For example, Kim et al. [35] developed a VR exposure program in which participants delivered presentations in a virtual environment. Another utilization of this type involved addressing nicotine cravings among adolescents by employing virtual bar settings featuring elements such as cigarettes placed on tables, bottles, glasses, cigarette lighters, and ashtrays accompanied by two avatars smoking cigarettes [31].

The second category encompassed VR programs designed for training and missions, which were the subjects of investigation in five studies [32,33,37,41,42]. For instance, Lee [33] developed a social orientation training program that incorporated a VR bus commute module, including elements such as traffic safety education and training scenarios like "moving to the bus stop," "waiting for the bus," "boarding the bus," "using a bus card," and "alighting from the bus" [33].

The third type encompasses VR healing content developed in a single study [39]. This study provided six primary images through a VR forest healing content, including a forest trail, lake and sky, waterfalls and streams, sky or sea with birds, mountain birds, wind sounds, and uninhabited islands with horizontal lines.

In non-experimental studies, the predominant VR content revolves around cognitive-behavioral approaches. For example, Ryu and Yeon [42] and Ryu [45] proposed that the content applicable to VR for anger management included self-understanding, cognitive restructuring techniques, and systematic desensitization through exposure to potential future stress by implementing various scenarios in VR. In addition, the researchers provided self-compassion training through past, present, and future scenarios and applied mindfulness-based therapy through audio and visual stimulation.

Second, we identified the content of the visual stimulation methods, such as providing images through 360 VR or 2D video environments [44] and physical activity games [46]. These art therapy and kinesiology studies have applied VR technology to art and physical activities, presenting them as employable content for adolescents' mental health. Finally, the researchers specified the content of ADHD diagnostic screening through VR [51]. As a professional diagnostic tool, it provides VR content, such as baseball and car assembly, based on VR's 3D environment implementation technology for diagnostic tests of ADHD. Subsequently, the researcher comprehensively analyzed the users' game method and results to determine the diagnosis and level of ADHD.

Only two [31,39] of the 12 experimental and three [42,44,46] of the 14 non-experimental studies examined provided a comprehensive account of the development process for their program contents. For example, Lee et al. [31] indicated that they developed the content following a preliminary test. Jin and Kim [39] reported that they based their content on interviews and prior research conducted by two professors with expertise in the field.

Sample characteristics

All 12 experimental studies included participants to validate the XR program's effectiveness. The sample sizes ranged from six to 304. The mean of the sample size was 55.0 (SD= 77.3). The age range of the participants across the reviewed studies varied from 5 to 24 years, with most participants being adolescents. Specifically, four studies (33.33%) included college students aged 20 years and above. Regarding gender distribution, all studies except one (8.33%) [32] reported the gender percentage of participants. Male participants accounted for 50.81% (SD=34.66%) of the total sample, whereas female participants accounted for an average of 49.18% (SD= 36.20%). Notably, approximately 41.67% of the studies (n=5) focused exclusively on female (n=3, 25%) or male participants (n=2, 16.67%).

Target and measurement tools used to assess

Digital therapies employing XR technology to address the mental health concerns of adolescents in South Korea encompass a diverse range of target areas, such as social anxiety, public speaking anxiety, nicotine dependency, academic stress and test anxiety, ADHD, community adaptation skills, and anger control. Notably, within the subset of experimental studies, anxiety-related variables emerged as the most prominent targets of investigation, with six studies (50%) specifically focusing on various forms of anxiety, including social, heterosocial, public speaking, and test anxiety. Additionally, three studies (25%) considered aspects related to sociality, such as social adaptability and community adaptation skills.

All 12 experimental studies included in the analysis incorporated a measurement tool to assess the efficacy of VR programs in enhancing or reducing the target variables. Ten (83.33%) employed standardized scales as their chosen measurement instruments. In contrast, the remaining two studies (16.67%) used nonstandardized questions.

Of the 14 non-experimental studies, three addressed ADHD [45,51,53] and two addressed post-traumatic stress disorder (PTSD) [43,47]. Other factors include game overindulgence [46], anger management [42], school violence [23], relief from preoperative anxiety in children [52], career stress [44], military [48], or youth shelter adjustment [50], and general mental health promotion [22,49]. These non-experimental studies explored the application of AR or VR technologies to pre-

vent and promote mental health, including mental illness, and present program models.

Effectiveness of the program in experimental studies

Of the 12 studies that examined the effectiveness of developed VR programs, approximately 60% (n=7) reported positive effectiveness with a significant p-value. For instance, Jin and Kim [39] reported that the VR forest healing program reduced academic stress ($p<0.001$) and test anxiety ($p<0.01$). Conversely, two papers (16.67%) indicated the efficacy of the program exclusively for certain variables. Nonetheless, they did not demonstrate statistical effectiveness for other variables. Kim [34] found a significant reduction in Test Anxiety Inventory (TAI) emotionality ($p<0.05$), whereas TAI worry did not exhibit a significant reduction ($p=0.084$). Moreover, three papers (25%) opted not to conduct a statistical examination of the program's effectiveness; instead, they administered a satisfaction survey. Nevertheless, these studies reported consistently high scores, as exemplified by Jung and Oh's [37] investigation, which yielded an average response score of 4.57 out of 5 for the program. Furthermore, none of the 26 studies analyzed in the present study (100%) included control variables in their models.

Main findings (outcomes) in non-experimental studies

The characteristics of non-experimental studies include presenting XR programs and exploring the potential of XR digital therapies as the primary outcomes. These features had three main themes. First, the convergence of VR technology with various existing psychological therapies highlights the potential of VR to improve mental health in the general youth and be more accessible to juvenile offenders and youths experiencing conditions such as ADHD [53], impulse control disorders [45], and PTSD [43].

Second, the researchers argued that the VR technology would enable the application of various options according to individual psychological and environmental characteristics, thereby increasing the effectiveness of interventions. Researchers can use the system in private spaces without face-to-face contact [47]. Programs can use appropriate scenarios to prevent mental health issues and enhance mental health, including psychotherapy [43] and social adjustment [22,23,48-50].

Third, it reduces the professionals' workload. Ryu and Yeon [42] argued that VR-enabled digital therapy programs could reduce the time spent on a therapeutic alliance between therapists and clients and prevent burnout due to aggressive and resistant clients. Additionally, Ryu [51] noted that accuracy and reliability could be secured by aiding doctors' diagnoses.

DISCUSSION

This study systematically reviewed XR digital therapies for the mental health of South Korean adolescents and young adults in the context of the growing efficacy of XR technology for digital therapies. Based on the PRISMA guidelines, 26 studies were included. Notably, among these 26 studies, only 46.15% employed an experimental research design, whereas over 53% utilized non-experimental approaches. These results suggest that XR-based digital therapies have not been sufficiently developed or validated in South Korea, limiting their practical application. Consequently, there is a pressing need for additional experimental research that delves into developing digital therapies utilizing XR technology. In particular, to address mental health issues among adolescents in South Korea while simultaneously assessing the effectiveness of such treatments.

A total of 60% (n=7) of the experimental studies demonstrated the significant effectiveness of the developed VR programs. However, we observed notable limitations among the 12 experimental studies. These limitations include using non-genuine experimental designs such as the one-shot case study design (25%) and the one-group pretest–posttest design (8.33%). Moreover, 16.67% of the studies employed non-standardized questions to evaluate the effectiveness of therapy, and none incorporated control variables into their models. Consequently, conducting studies using more structured methodologies is crucial for achieving enhanced realism and validity.

We divided the non-experimental studies into literature reviews and program development studies related to XR content. All eight literature reviews examined the feasibility of using XR technology to address various mental health issues among adolescents and young adults. In particular, multiple disciplines, such as kinesiology and corrections, including multidisciplinary studies, have positively reviewed XR-based digital therapies. These results show that XR technology can be applied to many mental health issues, not just adolescent mental illnesses. However, these studies have limitations as only three provided specific literature inclusion criteria. Therefore, researchers must present the literature selection criteria and scope to ensure reliability and validity even for a literature review.

Over 85% of experimental and non-experimental studies have overly focused on VR, among other XR technologies. However, AR effectively applies exposure therapy among XR technologies for mental health overseas. In contrast, MR is a technology that can realize therapeutic experiences in the real world rather than in a simulated environment [11]. Therefore, researchers should examine the applicability of AR and

MR.

Additionally, only 16.67% of experimental studies provided explicit information on the duration of each session. Similarly, in the case of program development studies, only two of the four studies provided specific sessions, and only one provided VR usage time, which was inconsistent. Thus, it is necessary to develop detailed research models. In particular, in the case of VR, there is a possibility of side effects when using HMDs [54,55], so it is necessary to present standards for device usage time per session.

Moreover, as most participants in the experimental studies were adolescents, it is essential to note that adolescents may experience adverse effects, such as minor headaches when exposed to VR [54]. Additionally, constant exposure to VR can distort reality and lead to unrealistic expectations [55]. For example, VR and AR 3D immersive environments that allow users to modify themselves in VR or AR could increase the risk of mental health deterioration [56]. Therefore, caution should be exercised when using XR techniques, particularly in adolescents.

Noteworthy, approximately 41.67% of the studies (n=5) focused exclusively on female (n=3, 25%) or male participants (n=2, 16.67%). However, these studies did not provide gender-specific content in their programs. Therefore, it is imperative to develop and validate gender-integrated programs or design gender-specialized programs that incorporate content tailored to each gender.

This systematic review had several limitations. First, the mental health keywords employed to screen the relevant studies may not have been exhaustive. We extend the scope of this study by incorporating a more comprehensive range of mental health keywords during the screening process. Furthermore, we acknowledge that we confined this review to South Korea. Therefore, we recommend that future studies expand beyond South Korea to include comparative analyses involving multiple countries.

CONCLUSION

Given the increasing effectiveness of XR technology in digital therapies, this study systematically reviewed XR digital therapies targeting the mental health of South Korean adolescents and young adults. The analysis revealed limitations in the design complexity of the experimental and non-experimental studies. The findings of this systematic review serve as a valuable foundational resource for enhancing the implementation of XR-based digital therapies for South Korean adolescents and young adults, catering to the needs of this specific population.

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