Effects of Digital Interventions on Neuroplasticity and Brain Function of Individuals With Developmental Disabilities: A Systematic Review

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Abstract

Background: Developmental disabilities (DDs) impact individuals' cognitive, psychological, and motor functions, and those with DDs show specific neural differences. Research suggests the importance of interventions to enhance neuroplasticity, which is the brain's ability to adapt to stimuli, as well as effectiveness of digital interventions for this population. However, there is a lack of comprehensive review on intervention outcomes from relevant existing studies.

Objective: This systematic review aimed to investigate the effects of digital interventions on neuroplasticity and neural functions of individuals with DDs.

Methods: Based on the Joanna Briggs Institute guidelines, a systematic review was conducted on PubMed, PsycINFO, CINAHL, and Scopus databases. Studies that focused on digital interventions to enhance neuroplasticity of individuals with DDs and used neuroimaging methods to evaluate the effectiveness were included. The results of the current review were synthesized based on Roy's adaptation model.

Results: Of the 2824 retrieved studies, 30 were included in this review. The included studies used cognitive training, neurofeedback, and social cognitive training integrated with digital devices, mostly virtual reality. Neuroimaging results after digital interventions demonstrated changes in brain wave patterns and increased activation in certain regions. Behavioral assessments exhibited significant improvements including attention- deficit/hyperactivity disorder symptoms, attention, emotional recognition, and social skills than before the intervention.

Conclusions: Digital interventions are promising in enhancing neural functions and neuroplasticity in individuals with DDs. Further studies with diverse methodologies and a broader spectrum of DDs are essential to fully understand the potential of digital interventions in neurodevelopmental challenges among the population.

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Review

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Keywords: Developmental disabilities; Digital Intervention; Neuroplasticity; Neural function; Neuroimaging; Attention-Deficit/Hyperactivity Disorder; Autism Spectrum Disorder; Neurofeedback; Computerized Cognitive Training; Virtual Reality Therapy

Introduction

Developmental disabilities (DDs) are a spectrum of long-term conditions that impact individuals' cognitive, physical, psychological, language, and self-care capacities [1]. The characteristics of brain function in individuals with DDs vary between people and by the type and severity of the disability. Nonetheless, commonalities in brain functions in DDs including unfavorable levels of cognitive and social skills, as well as perceptual-motor functions have been identified [2-4].

Cognitive deficits in individuals with DDs manifests as impairments in executive functions, attention spans, and language competency [5-7]. These individuals also demonstrate weaknesses in the fundamental brain functions of emotion and behavioral regulation through various challenges such as elevated anxiety and depression symptoms and aggressive behaviors compared to their counterparts without such disabilities [8-10]. Motor skills are contingent upon neural function and the interplay of physical practice with environmental feedback, and individuals with DDs consistently exhibit lower levels of motor planning, control, and coordination relative to those without DDs [11,12].

Furthermore, various neuroimaging assessments have been employed to establish objective metrics for detecting abnormalities in brain structure and function in DDs, including structural magnetic resonance imaging (MRI), diffusion tensor imaging (DTI), functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and functional near-infrared spectroscopy (fNIRS) [4]. Research using neuroimaging assessments for individuals with DDs has exhibited unique features of the brain. The fMRI studies show distinct reductions in functional connectivity and activity within “social brain” regions (eg, medial prefrontal cortex, superior temporal cortex, and amygdala) and in the cerebellum and corpus callosum, which play integral roles in modulating interactions within these social brain regions [13]. EEG studies have indicated deficits in event-related potentials (ERPs) which are associated with executive functioning, auditory and visual processing, and overall cognitive functioning. Additionally, certain changes in brain wave patterns indicative of attention-deficit hyperactivity disorder (ADHD) have been reported, distinguishing them from those of neurotypical control groups. Individuals with ADHD typically exhibit elevated relative theta power and reduced relative alpha and beta powers during resting EEG, along with increased theta/alpha and theta/beta ratios [14].

These pervasive neurological characteristics intrinsic to DDs exert a profound influence on every aspect of individuals' lives. This has resulted in a substantial body of research developing interventions to enhance neurological functions in individuals with DDs, finally impacting their neuroplasticity. Neuroplasticity, also known as brain plasticity, refers to the nervous system's ability to adapt in response to different stimuli such as development, learning, environment, disease, and interventions; this process includes adaptive structural and functional changes in the brain [15,16].

Research suggests the positive effects of interventions aimed at enhancing neuroplasticity in individuals with DDs [15]. For example, neuroplasticity is facilitated by invasive/non-invasive brain stimulation techniques, including transcranial magnetic stimulation and electrical current application via implanted electrodes [15]. Physical training and exercise interventions, such as constraint-induced movement therapy, aerobic exercise, and circuit-based training, are recognized as effective strategies for inducing positive neural effects in individuals with DDs [4,15]. Additionally, cognitive trainings such as meditation-based therapy, cognitive behavioral therapy (CBT), and neurofeedback have been empirically reported to enhance various cognitive functions (eg, inattention, working memory, inhibition, and executive functions) in individuals with DDs [17].

With the development in digital technologies, research on technology-integrated interventions to enhance neuroplasticity in individuals with DDs has been increasing [18]. Studies employing digital technologies such as games and virtual reality (VR) showed positive effects on brain functions including cognitive functions and motor skills in individuals with DDs [11]. Despite the efforts to incorporate interventions facilitated by digital devices, a comprehensive synthesis of research outcomes from the relevant studies is absent [19]. Therefore, this study aimed to elucidate the contribution of digital interventions to enhance neuroplasticity in individuals with DDs. Furthermore, it synthesized data on digital interventions to enhance neuroplasticity and brain functioning of the population based on Roy's Adaptation Model (RAM), which elucidates how individuals adapt to environmental changes to maintain health and wellness[20].

Methods

This systematic review followed the Joanna Briggs Institute methodology [21] to explore the effects of digital interventions on brain functions of individuals with DDs[21]. The protocol was registered under the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42023452565).

Selection Criteria

The inclusion criteria was defined based on the population, intervention, comparison, outcomes, and study type (PICOS) framework. Population included individuals with DDs, with health conditions since their developmental period. These disabilities included, but were not limited to, ADHD, autism spectrum disorder (ASD), dyslexia, or dyscalculia.

Interventions comprised digital interventions targeting neuroplasticity and brain functions in individuals with DDs. These interventions encompassed various strategies utilizing digital technologies, such as mobile apps, websites, and digital platforms, as well as wearable devices to deliver health-related services [22]. Comparisons could be either with in-person interventions or other control interventions. Articles without a comparison were also included, reflecting the aim of the review to comprehensively investigate digital interventions, rather than solely identifying their relative effects.

Outcomes were primarily brain functions measured via neuroimaging technologies, including EEG, MRI, or fMRI. Articles that did not measure brain functions or neural patterns with such modalities were not included. However, other additional measurements and their outcomes in the relevant studies were considered to provide integrated results. Some additional outcomes included symptoms related to the disabilities or task performance. All were included as long as they provided reliable evidence. Only articles with full text in English were included, while qualitative studies, clinical guidelines, and review articles were excluded.

Search Strategy

A comprehensive literature search was conducted on June 2, 2023, on the following online databases: PubMed, PsycINFO, CINAHL, and Scopus. Search terms employed three primary groups based on preliminary scoping search and existing knowledge regarding the topic: (1) diagnostic terms, which were related to neurodevelopmental disorders (e.g, “Autism spectrum disorder,” “Attention-deficit/hyperactivity disorder,” “Developmental coordination disorder,” “Learning disorder," and "Intellectual disorder"); (2) intervention terms, related to digital interventions (eg, "Digital" and "Computer"); and (3) neuroimaging terms, related to neuroimaging modalities (eg, "Electroencephalography," "Magnetic resonance imaging," and "Near-infrared spectroscopy"). The search strategy was developed in collaboration with the librarian of Yonsei Medical Library (*Appendix 1*).

Study Selection

The search results were imported into Covidence[23]a web-based program for systematic review management. After eliminating duplicates, first, the titles and abstracts and subsequently, the full-texts were screened. At each stage, two reviewers independently determined each article's eligibility based on the preset criteria. Any conflicts between the two reviewers were resolved by the corresponding author.

Quality Assessment

Quality assessment criteria were accorded based on the Mixed Methods Appraisal Tool (MMAT) [24], version 2018 to ensure the quality of the included studies. This tool evaluates empirical studies of different designs, included in a systematic review, and offers distinct checklists for each study design, thereby enhancing precision in assessment. Based on answers ("yes," "no," or "can't tell") to five questions, a score ranging from 0% to 100% is obtained for each article. In this study, two researchers cross-evaluated each article to determine its eligibility. Articles with scores below 60% were excluded.

Of 32 retrieved studies, six were evaluated using the randomized controlled trial (RCT) checklist while the remaining 26 were assessed with the non-RCT checklist. All the six RCTs met the eligibility criteria, with one (17%) scoring 100%; three (50%), 80%; and two (33%), 60%. Of the 26 non-RCTs, 24 met the inclusion criteria, with 11 (42%) scoring 100%; seven (27%), 80%; and six (23%), 60%. Most articles that did not meet the threshold either did not have an assessor-blind design or omitted potential confounders. Thus, after the quality assessment, 30 articles were included in the review. The detailed results of the quality assessment can be found in *Appendix 2[3,25-53]*.

Data Extraction and Synthesis

From the PDF of each included study, the data were systematically extracted a using a structured template. The data encompassed purpose, design, participant demographics, interventions, and outcomes of each study. Each member of the research team thoroughly examined the extracted data for accuracy and completeness. After a discussion aimed at achieving consensus, the corresponding author implemented the necessary revisions.

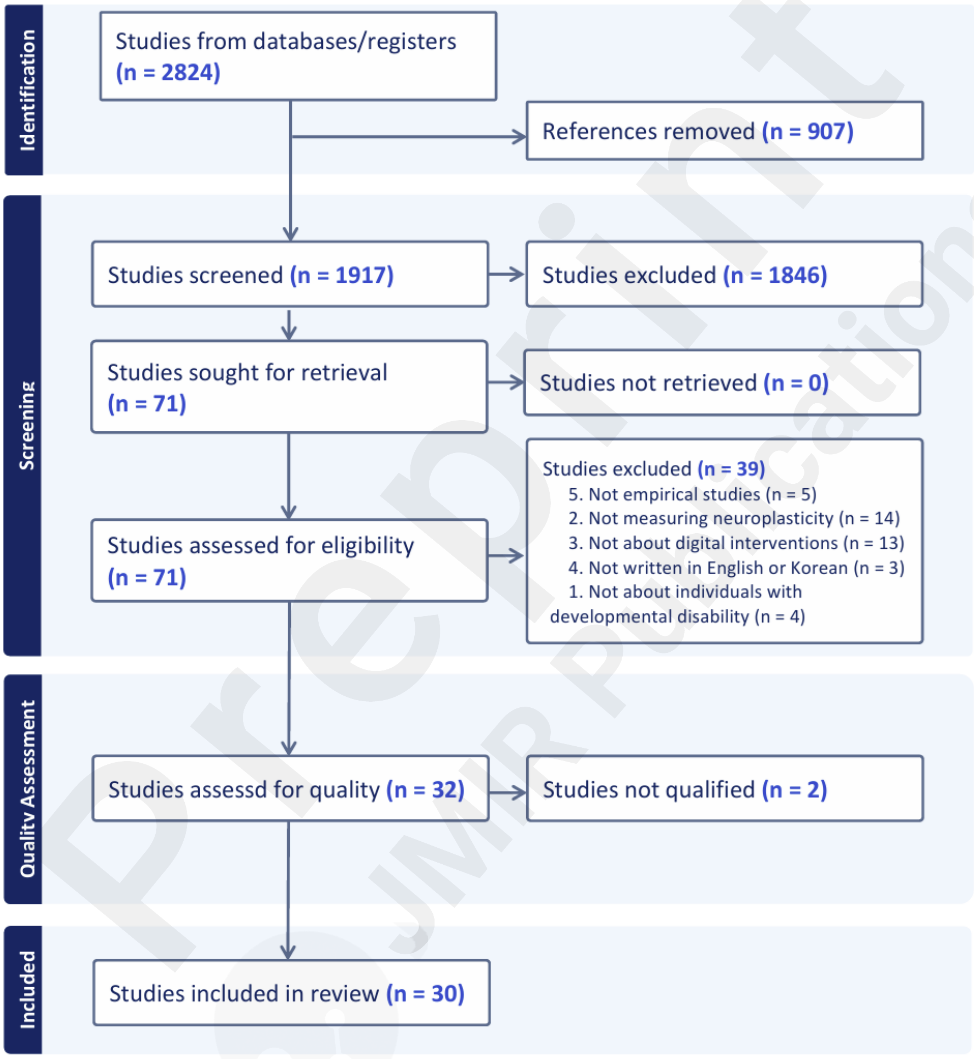
This study used the key concepts of RAM[20] to organize and visually represent the extracted data regarding the interventions. The RAM is a conceptual framework that assesses the adaptation level of an individual or group, which is a result of the coping strategies employed to manage internal or external stimuli. It has been widely utilized as a theoretical framework in studies examining the effects of interventions for people with chronic health conditions [54,55]. The RAM views human beings as adaptive systems that strive to achieve a state of adaptation, which entails living in integration with their surrounding environment. When exposed to various stimuli, a human being, or the adaptive system, activates coping strategies to respond effectively and finally enhance its adaptation.

In this study, digital interventions corresponded to external stimuli to the adaptive system. The target brain functions of these interventions were matched with the coping strategies of the adaptive system. The observed adaptive or maladaptive responses were reflected in the neuroplasticity of the participants.

Results

Study Characteristics

The initial literature search yielded 2824 studies. After removing duplicates, the titles and abstracts of 1917 studies were screened; thereafter, full text of 71 articles were reviewed. Finally, 30 studies met the inclusion criteria (Figure 1).



The characteristics of the selected studies are outlined in *Appendix 3[3,25-53]*. The included literature spanned from 2005 to 2023, with studies over the last five years (2018–2023) constituting 63% (N=19), indicating a significant recent increase in research. The majority of studies (23%, n=7) were conducted in the United States, followed by Germany (16%, n=5), and South Korea (10%, n=3) [29,35,47]. Other countries included China, Singapore, and Spain, with two studies in each. Pretest-posttest design was the most prevalent, accounting for 33% (n=10), followed by RCTs (26%, n=8) and pretest-posttest pilot studies (23%, n=7). Additionally, there were two case studies (6%, n=2) [33,51], two post-test studies (6%, n=2) [42,53], and one pilot RCT (3%, n=1) [31].

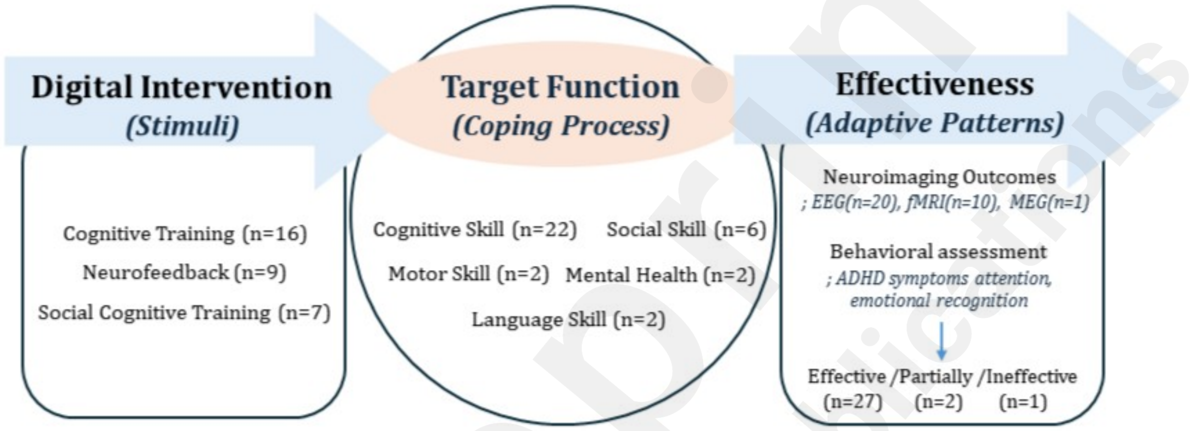
Participant Characteristics

The systematic review encompassed 1410 participants, with 1201 in the intervention group and 209 in the control group. Sample sizes varied from 3 to 560 participants. Of the 30 articles, 53% (n=16) focused on ADHD, 33% (n=10) on ASD, 6% (n=2) on dyslexia[36,50], and one each on developmental dyscalculia[28] and Down syndrome[48]. The participants' age ranged from 6 to 65 years, with 76% (n=23) studies targeting participants under the age of 20.

Synthesis of the Results According to RAM

Stimuli

According to RAM, stimuli are conceptualized as inducers of responses within the system [20]. This review operationalized the concept of "stimuli" as digital interventions targeted at influencing neural functions in individuals with DDs. The digital interventions identified in this review were cognitive training (n=16), neurofeedback (n=9), and social cognitive training (n=7). To deliver these interventions, the studies employed digital devices including computers, VR, and mobile applications with utilization rates of 63% (n=19), 20% (n=6), and 16% (n=5), respectively(Figure2).



Cognitive training was the most frequently-used intervention with methods such as memorizing cards, practicing calculations, or responding right signals; these interventions predominantly targeted individuals with ADHD (n=8) but also extended to those with dyslexia (n=2)[36,50], ASD[43], developmental dyscalculia[28], and Down syndrome[48]. All cognitive training interventions were primarily delivered in the form of games. For instance, in the study by Johnstone et al. [36], individuals with ADHD were required to rapidly take "Go" / "No go" decisions upon viewing a picture that indicated a "Go" response on a computer monitor. The participants had to click on boxes to reveal hidden bananas, which were then fed to a monkey. On average, cognitive training interventions were provided over 5 to 8 weeks, with a total of 20 to 36 sessions. The sessions lasted between 15 to 30 minutes, indicating relatively shorter durations compared to neurofeedback and social cognitive trainings.

Neurofeedback was the intervention in nine studies, with seven targeting individuals with ADHD and two focusing on those with ASD[39,51]. Neurofeedback involves participants in particular tasks while monitoring real-time brain activity signals such as EEG. Subsequently, feedback corresponding to changes in brain waves is provided in various forms during the task, aiming to induce specific changes in brain wave patterns. For example, in Pop-Jordanova's [25] study, participants received audio and visual feedback when they met specific conditions related to brain waves: beta amplitude exceeded its threshold, while theta amplitude remained below its threshold. Through this feedback, researchers sought to increase beta bands and decrease theta bands in EEG to enhance attention levels in individuals with ADHD [25]. Neurofeedback session durations ranged from 15 minutes to 1 hour, and were conducted between 2 to 40 times. The total duration of intervention ranged from 2 days to 24 weeks.

All seven studies employing social cognitive training targeted individuals with ASD. Social cognitive training was mainly delivered to train facial affect recognition. Additionally, it involved learning appropriate behaviors in scenarios resembling virtual social situations. In Bölte's[26,32] studies, researchers employed the Frankfurt Training for Facial Affect Recognition, a computer-based social cognitive training program. During the intervention, participants with ASD were exposed to 500 facial affect teaching items representing seven basic emotional states through educational text and comics [26,32]. Social cognitive training sessions lasted between 20 minutes to 2 hours, with interventions spanning from 3 to 18 sessions. These interventions were administrated to participants for 5 to 12 weeks.

Coping Mechanisms

"Coping mechanisms" in RAM define how individuals manage internal and external stimuli [20]. This review adopted the targeted neural functions of the digital interventions as the concept of "coping mechanisms." The included studies targeted cognitive competency (n=22), social competency (n=6), motor competency (n=2)[43,48], language competency (n=2)[36,50], and mental health (n=2)[43,49].

A total of 22 studies aimed at enhancing cognitive abilities specifically targeted improvements in attention (n=12), working memory (n=5), inhibitory control (n=4)[27,38,40,52]. The interventions sought to improve cognitive skills that are often deficient in individuals with ADHD, ultimately aiming to alleviate ADHD symptoms.

Six studies that aimed to enhance social skills focused on improving facial affect recognition and social interaction skills and were conducted with individuals with ASD. In the realm of motor skills, abilities such as motor coordination and equilibrium have been observed. De Luca [45] aimed to enhance the equilibrium and motor coordination of individuals with ASD using a VR therapy. In this study, participants engaged in games such as mole catching or apple finding in a VR environment, encouraging the movement of both arms [43]. In Lope's [33] study, VR therapy targeted upper limb movement in individuals with Down syndrome by requiring them to touch balls that changed color on a screen.

Two studies targeted language skills in individuals with dyslexia. Junttila et al. [34] implemented a mobile app-based language-learning game that used speech recognition technology. Participants articulated English words in a board game format and received stars as feedback from an automatic speech recognizer to incentivize precise pronunciation [34]. In Koen's [32] study, participants played "FlashWord," a computerized learning language game. It required participants to decide whether two letter strings presented simultaneously matched each other or whether a specific letter sound the same as the other [36].

Research identifying coping mechanisms within the domain of mental health focused on anxiety and general mental health conditions. De Luca et al. [45] identified anxiety as the target function in individuals with ASD. In the study, breathing training based on CBT was integrated into the final stage of VR-based cognitive training, to mitigate anxiety symptoms in individuals with ASD [43]. In Whitehead's [49] study, researchers provided neurofeedback therapy to individuals with ADHD using a mobile application. Through this application, participants received personalized neurofeedback protocols aimed at improving mental health [49].

Adaptive Patterns

RAM states that through coping process, individuals develop adaptive patterns [20]. Researchers have interpreted indicators of intervention effectiveness as "adaptive patterns." This review analyzed the effectiveness of the included studies according to the outcomes from neuroimaging methods and behavioral assessments. Interventions were effective in 90% (n=27), partially effective in 6% (n=2) [34,35], and ineffective in 3% (n=1) of the studies [53]

In terms of neuroimaging methods, most of the included studies used EEG to assess neuroplasticity (n=20), followed by fMRI (n=10), and magnetoencephalography (MEG)(n=1)[45]. A total of 18 studies that measured neuroplasticity using EEG assessed the magnitude of specific brain waves and the amplitude of the waves in the regions of interest. Additionally, three studies used ERPs[27,40,48], while De Luca's [45] study assessed functional connectivity using EEG measurements [43]. In studies investigating changes in brain waves, the predominant waves measured were theta (n=10), alpha (n=6), beta (n=7), and theta/beta ratio (n=6). In 8 out of 10 studies, theta waves decreased following the intervention. Three studies reported an increase in beta waves[25,46,47], two showed no difference[27,52], and one indicated a decrease[34]. Of the six studies measuring alpha waves, four reported increase[27,33,34,47], while of the six studies measuring theta/beta ratio, three reported decrease[25,38,47]. Of the articles that utilized fMRI to assess participant's neuroplasticity, 50% (n=5) observed blood oxygenation level-dependent (BOLD) signals to ascertain the impact of the intervention on neuroplasticity. Most studies revealed a notable trend of increased BOLD signal following the intervention (n=4)[3,26,32,35].

In addition, the reviewed studies employed various behavioral assessment methods to evaluate the effectiveness of the interventions including ADHD symptoms (n=13), attention (n=5), emotion recognition (n=5), and social skills (n=4)[25,35,41,51]. Additionally, two studies examined behavioral problems[33,37], executive function[45,47], and response inhibition[27,52].

ADHD symptoms were evaluated utilizing assessment tools such as the ADHD Rating Scale. Except for one study [53], those measuring ADHD symptoms indicated that digital interventions were effective in alleviating ADHD symptoms. Attention was assessed through methods such as the Continuous Performance Task (CPT) that evaluates participants' attention level using their reaction time and error rates. Except for one study[53], all four studies, reported an improvement in attention following the interventions[38,43,45,47].

Emotion recognition was assessed using instruments such as the Frankfurt Test for Facial Affect Recognition test, Emotion Recognition Test, and Advanced Clinical Solutions-Social Perception subtest. These instruments assigned facial emotion recognition tasks and evaluated the performances. Positive outcomes were evident in all studies that assessed emotion recognition. Social skills as an outcome were assessed using the Social Communication Questionnaire (SCQ), the Conners Parent Rating Scale, and Movie for the Assessment of Social Cognition (MASC). The Conners Parent Rating Scale and SCQ were survey-based measurement tools where parents or participants assessed social skills. In the case of the MASC, participants were presented with specific tasks while watching movies depicting social situations. Subsequently, trained evaluators assessed social skills by observing their performance. The social skills were enhanced across all these studies.

Discussion

This review consolidated findings from 30 peer-reviewed published studies, assessing the impact of digital interventions on neuroplasticity and brain functionality in individuals with DDs. An eminent feature of this review was its theoretical basis on an established conceptual framework, RAM. This theoretical underpinning facilitated a systematic approach of categorizing digital interventions (as stimuli), targeted brain functions (as coping mechanisms), and outcomes of these interventions (as adaptive patterns).

The current study clarified the effectiveness of digital interventions on the neurological functions of individuals with DDs. Of the 30 reviewed studies, 28 reported positive outcomes in at least one neurological function. The current results are consistent with those of previous reviews that reported positive possibilities of the integration of digital technologies into various interventions, training, or programs for individuals with DDs [56,57].
In this review, only Selaskowiski et al.'s[53] study did not report significant improvements in children with ADHD. The researchers provided audio-visual feedback based on eye movements to increase self-awareness of eye movements and alleviate ADHD symptoms. However, individuals with ADHD perceived the feedback as a distraction due to their susceptibility to external stimuli, leading to a worsening of ADHD symptoms. They also observed that a single-session intervention was inadequate to address cognitive skills [53]. Although the effectiveness of digital interventions is highly plausible, it is critical to consider various characteristics of DDs which may be suitable for the features of digital interventions. This is further supported by Jiang and Johnstone[33], who reported unintended changes in EEG waves. The researchers attributed the cause of these changes to a failure in difficulty adjustment because individuals with ADHD can improve their cognitive abilities by practicing at an appropriate level of difficulty, which facilitates achievement[33].

This review identified three main intervention types used by included studies to enhance the neural functioning of individuals with DDs: cognitive training, neurofeedback, and social cognitive training. These interventions were integrated with digital devices, showing a trend of moving from computer-based to tablet or mobile-based approaches. Specifically, the current findings demonstrated that most of the reviewed studies utilized cognitive training interventions targeting the "attention" of individuals with ADHD. While there were individuals with other types of DDs, such as ASD or Down syndrome, studies focusing on populations with ADHD and their often-reported cognitive deficiencies predominated this review. Digital interventions aimed at individuals with intellectual disabilities are also reporting their effectiveness in improving their cognitive or behavioral functions [56,57]. Further research concerning populations with different DDs and interventions that integrate emerging digital technologies to enhance brain function is essential.

In addition, it would be beneficial to explore the diverse content of interventions that can be integrated into digital platforms, particularly those that can enhance neuroplasticity. Cognitive training, neurofeedback, and social cognitive training identified in this review required participants to remain sedentary while completing tasks aimed at enhancing neuroplasticity. However, researchers suggest various approaches, such as movement therapy (eg, exercise), to enhance neuroplasticity in individuals with DDs [4,58,59]. This review included studies that conducted digital interventions to enhance the neural functions of individuals with DDs as well as evaluated the effects of these interventions using neuroimaging methods. This might be the reason for excluding studies of various interventions (eg, movement therapy for neuroplasticity of individuals with DDs but not integrated in digital devices). Future studies should evaluate the effects of various intervention contents that integrate digital technologies.

Furthermore, our findings indicate that only two studies [35,43] utilizing CBT were based on a defined theoretical framework. There is a concern among researchers that many digital interventions lack a solid theoretical basis, leading to insufficient justification for their use [60]. It is recommended that researchers design digital interventions that are grounded in well-established theoretical frameworks.

In terms of the neuroimaging methods identified in this review, EEG and fMRI were predominantly utilized to elucidate the changes in the brains of individuals with DDs. Of the 20 studies that analyzed EEG, 14 targeted individuals with ADHD. There was a consistent trend indicating a decrease in theta waves and theta/beta ratio, which could be interpreted as normalization of characteristic abnormal brain wave patterns seen in individuals with ADHD. This is because individuals with ADHD typically exhibit higher theta band activity and theta/beta ratio compared to those without it [61].

Of the 10 studies that analyzed fMRI data, six targeted individuals with ASD, aiming to improve their social skills and emotional recognition abilities through interventions. The findings of these studies suggested an increase in indicators of brain activation such as the BOLD signal. The investigators identified activation in the "social brain" area, which is responsible for social cognition skills, particularly emotion recognition. The studies revealed an augmented activation in the social brain network associated with analyzing faces and gaze, such as the fusiform gyrus and superior temporal sulcus. Additionally, areas associated with understanding the emotions and thoughts of others, such as the prefrontal cortex, also exhibited increased activity [62].

A comprehensive analysis of the neuroimaging results confirmed the possibility of mixed interpretations of the same findings. An increase in alpha waves in individuals with ADHD is generally considered a positive signal, and efforts are made to increase alpha waves. However, this review revealed a notable trend of decreased alpha waves following the intervention, leading to mixed interpretations of these results. Jiang and Johnstone [50] and Bekele et al. [31] argue that the intervention was not sufficiently effective for the participants, possibly due to failure in difficulty adjustment [33,34]. Johnstone et al.[27]and Ha et al.[47] suggest that decreased alpha waves cannot simply be interpreted as a negative response, given that the researchers did not sufficiently account for the diverse subtypes of neurological characteristics of the participants [27,47]. This indicates that due to the various neurological subtypes observed in individuals with ADHD, a universally consistent interpretation is not possible.

Furthermore, research on neuroimaging interpretation has not been extensively conducted, and neuroimaging is currently recognized as a supplementary factor in diagnosing and assessing ADHD and ASD [13,63]. Based on this review and recent research, it would be possible to propose considerations for neuroimaging interpretation when investigating the effects of interventions on neuroplasticity in individuals with DDs. First, it is essential to establish the correlation between neuroimaging findings and other behavioral assessments or clinical outcomes. Additionally, selecting participants with consistent neuroimaging-related subtypes across interventions can help eliminate additional variables that may influence neuroimaging results.
Finally, the included studies were concentrated in countries with well-developed information technology industries such as the United States, Germany, and South Korea. This is supported by a systematic review examining the application of digital technology on behavior change and highlighting this geographic limitation [61]. Digital technology can provide efficiency, leading to greater impact in vulnerable areas, thus emphasizing the need to pay attention toward digitally vulnerable regions [64].

Limitations

This review had some limitations. It included only full-text and English-language publications. Unpublished and ongoing studies, guidelines, protocols, and qualitative studies, and non-English publications were excluded. As a result, this may limit the interpretation of the findings. Despite these limitations, it provided insights into the application of digital interventions on individuals with DDs and allowed identification of their effects on neuroplasticity.

Conclusions

This review highlighted the promising potential of digital interventions integrated with cognitive training, neurofeedback, and social cognitive training, to improve neural functions and neuroplasticity in individuals with DDs. The interventions showed significant improvements. The positive outcomes have been proved through a reduction in abnormal brain wave patterns, increased activation in regions associated with social cognition, and positively influenced behavioral outcomes. Yet, additional studies including a broader spectrum of DDs and more diverse methodological frameworks are warranted to fully understand the effectiveness of digital interventions targeting neurodevelopmental challenges of the population.

Acknowledgements

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Conflicts of Interest

None declared.

Abbreviations

ADHD: Attention-deficit/hyperactivity disorder
ASD: Autism spectrum disorder
BOLD: Blood oxygenation level-dependent
CBT: Cognitive behavioral therapy
DD: Developmental disability
DTI: Diffusion tensor imaging
EEG: Electroencephalography
ERP: Event-related potential
fMRI: Functional magnetic resonance imaging
fNIRS: Functional near-infrared spectroscopy
MASC: Movie for the Assessment of Social Cognition
MEG: Magnetoencephalography
MMAT: Mixed Methods Appraisal Tool
MRI: Structural magnetic resonance imaging
RAM: Roy's adaptation model
RCT: Randomized controlled trial
SCQ: Social Communication Questionnaire (SCQ)
VR: Virtual reality

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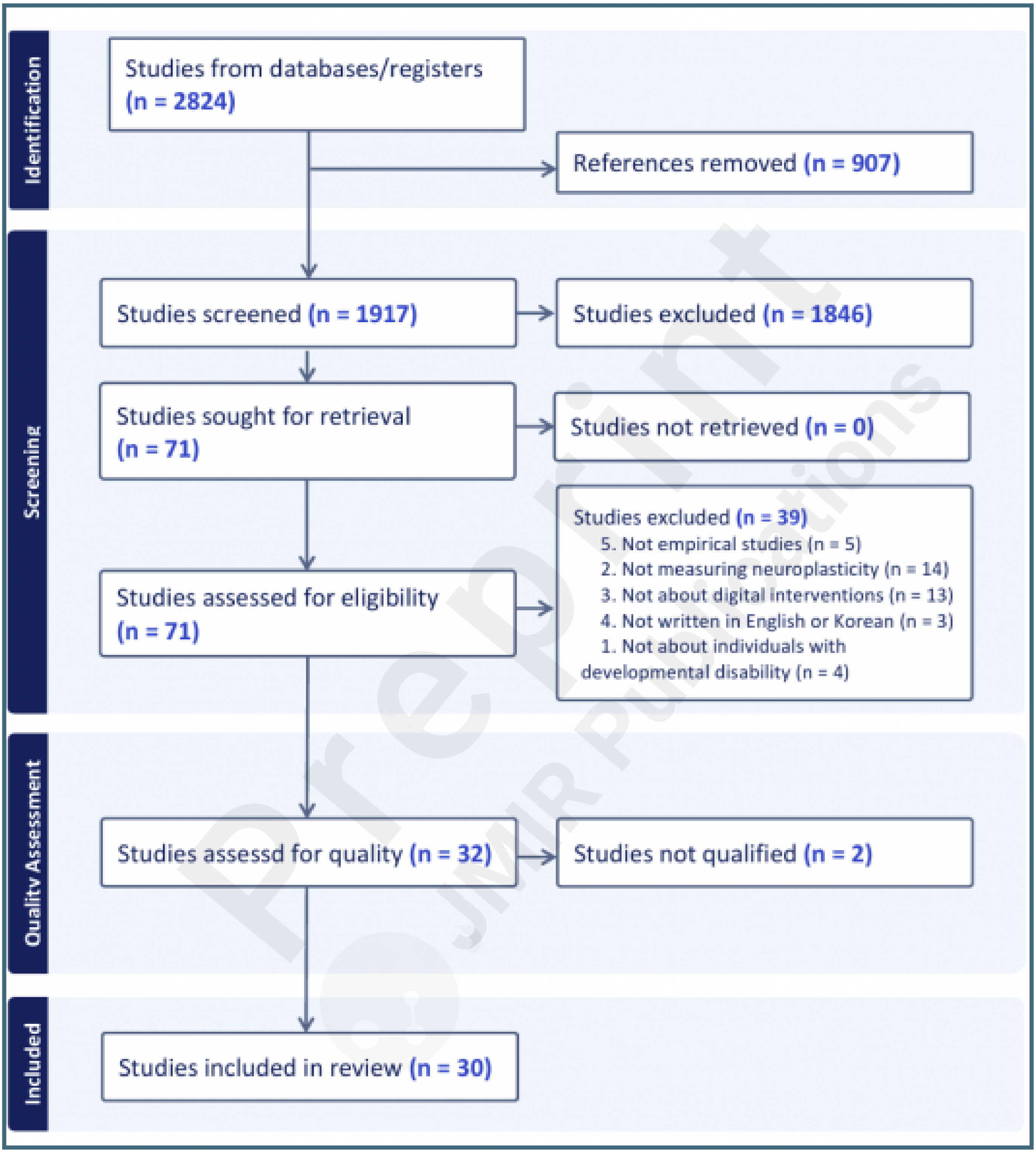
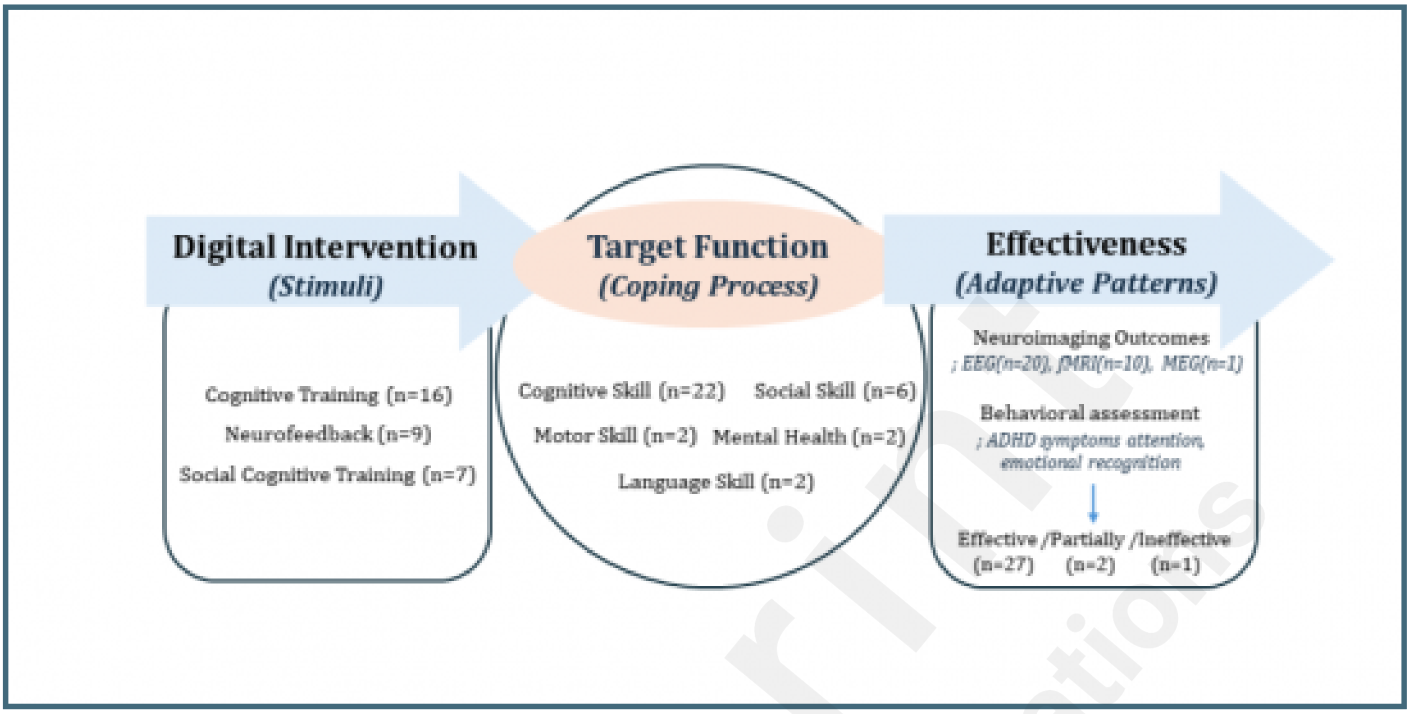
Supplementary Files

Figures

PRISMA chart.



Roy Adaptation Model.



Multimedia Appendixes

Detailed search terms.
URL: http://asset.jmir.pub/assets/d78f211fe31e0d2daf57e98b991a741d.docx

Quality Assessments included studies based on Mixed Methods Appraisal Tool.
URL: http://asset.jmir.pub/assets/4ecb94914422c1f40f077772a32634f0.docx

Characteristics of the included studies.
URL: http://asset.jmir.pub/assets/42ce886c3151f890373491d8977789d9.docx

Characteristics of the individual interventions.
URL: http://asset.jmir.pub/assets/25b568b075e144c91ffa21a9c68bc8d4.docx