

Review

A Systematic Review of the Use of Art in Virtual Reality

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Abstract: Brain injuries can create life-altering challenges and have the potential to leave people with permanent disabilities. Art therapy is a popular method used for treating many of the disabilities that can accompany a brain injury. In a systematic review, an assessment of how art is being used in virtual reality (VR) was conducted, and the feasibility of brain injury patients to participate in virtual art therapy was investigated. Studies included in this review highlight the importance of artistic subject matter, sensory stimulation, and measurable performance outcomes for assessing the effect art therapy has on motor impairment in VR. Although there are limitations to using art therapy in a virtual environment, studies show that it can feasibly be used in virtual reality for neurorehabilitation purposes.

Keywords: virtual reality; art therapy; rehabilitation; neurorehabilitation; neuroplasticity; brain injury



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1. Introduction

Art has been used as part of the healing process for a variety of therapeutic practices, including: mental health treatment, social problems, language and communication difficulties, medical problems, physical disabilities, and learning difficulties [1]. Art therapy involves interacting with a form of art to help patients through recovery. It works by using personal artwork from therapy, third-party artwork, or the creative process to help people explore their emotions or improve social skills. The creative process refers to the stages involved in transforming an idea into its final form. In art therapy the process is more important than the final masterpiece. The act of making art encourages creative expression without placing constraints on experience level. It provides an outlet where there are no right or wrong answers, and one is free to release any internal struggles and frustration that can form in the beginning stages of recovery [2].

As with most aspects of life, one size does not fit all and this holds true for therapy and rehabilitation. Researchers agree that the individualized treatment capability offered by the creative aspect of art therapy is essential for accommodating specific needs of patients [3–5]. By not requiring an end goal in art therapy, people have the ability to make their own choices and express themselves at their own pace and skill level. The individualization aspect of creative art therapy permits a wider range of patients to be treated and unleashes the potential for more therapeutic applications, including neurorehabilitation. Neurorehabilitation is the process of restoring the functions of the brain, usually for people who suffer from a neurological disease or brain injury. One main focus in neurorehabilitation is the plasticity of the brain, or its ability to make adaptive changes or form new connections in place of damage when exposed to environmental stimuli. Although plasticity occurs more in younger ages (developmental years) [6], it has also been found to occur in older ages at reduced levels [7].

One way to ensure the promotion of neural plasticity, regardless of age, is to have participants enter a creative state of flow [8]. Flow, one of the psychometric measures of creativity highlighted in Jung et al.'s (2010) study, has implications for promoting neuroplasticity [9]. Entering the state of flow is said to feel like being in autopilot mode—all focus

is on one activity, and everything else seems to fade away [8]. In art therapy, reaching the state of flow not only means achieving the optimal experience but also performing the activity successfully [4,8,9]. Jung et al. (2010) also found that creativity involves the activation within and between multiple brain areas, which has implications for use-dependent plasticity, healing individual parts of the brain [9]. Similarly, Makuuchi et al. (2003) found in their fMRI study that the following brain areas, shown in Figure 1, are activated during creative behavior: the parietal lobe, the premotor cortex, and the sensorimotor area (primary motor cortex and somatosensory cortex), among others [10]. These areas are considered to be involved in motor cognition [11], suggesting that art therapy can be used for restoring damaged motor areas of the brain and for inducing use-dependent neuroplasticity.

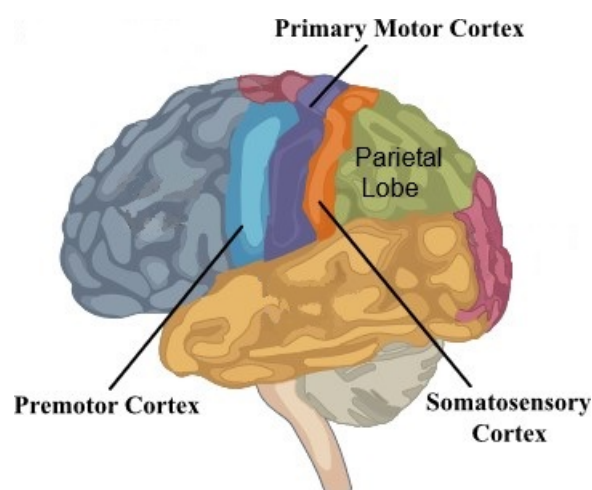


Figure 1. Some of the brain areas activated during creative behavior [12].

Promoting plasticity is vital for rehabilitating brain injuries. There are two types of brain injuries, traumatic, and acquired. An acquired brain injury (ABI) refers to any brain damage or alteration of brain function, i.e., stroke, tumor, or meningitis, that occurs after birth and is not hereditary or caused by a degenerative disease. A traumatic brain injury (TBI) refers to any brain damage or alteration of brain function caused by an external impact to the head, such as from a military blast. In 2016, roughly 27 million people suffered TBIs around the world [13]. In the United States, approximately 5.3 million people are currently living with a permanent disability caused by brain injury [14]. Typically after suffering from a TBI, patients are unable to recognize the injury's impact and cannot shift into a new sense of self [4]. Because they suffer from poor self awareness, brain injury patients can potentially benefit from the creativity component of art therapy, which allows for the rehabilitation of self awareness, helping patients adapt to their new disabilities [15]. Of the disabilities that can form after brain injury, including problems with behavioral and mental health, sensory processing, and communication, motor impairment will be the focus of this investigation.

Traditional methods of art therapy often requires a hands-on approach that excludes many people suffering from cognitive and motor impairments. With the technological advancements happening in the realm of human-computer interaction, new and innovative systems are being created to provide treatment to those excluded from the traditional methods of art therapy. Virtual reality (VR) systems are being used as an alternative modality to the traditional methods of therapy. Because VR is a real-time simulation of an environment, it has the capacity to accommodate the specific needs of elderly and impaired populations. In an effort to rehabilitate impaired motor functioning, researchers have studied the effect of VR on motor rehabilitation and have found it to aid in the rehabilitation of physical impairment [16–23]. With evidence supporting the use of VR in rehabilitative practices for motor impairment, an investigation into the efficacy of using art therapy in VR for neurorehabilitation needs to be conducted.

2. Objectives

This systematic review consists of an exploratory analysis of how art therapy is being used in VR for neurorehabilitation in non-adolescent people. To formulate the research questions guiding this review, the PICO (Population, Intervention, Comparison, Outcome) format was used [24]. The following research questions will be investigated and answered:

1. What is the feasibility for non-adolescent brain injury patients to experience art therapy for motor neurorehabilitation in a virtual environment?
2. What are the limitations of performing art therapy in VR?

To adequately assess the limitations presented by VR, studies involving art therapy for neurorehabilitation in a non-VR setting are also included in this review.

3. Methods

A systematic review conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was performed using Google Scholar, ScienceDirect, and PubMed. The following keywords were used to find relevant studies: “art”, “art therapy”, “brain injury”, “virtual reality”, “neurorehabilitation”, and “motor rehabilitation”. If an article’s title related to the objectives of this systematic review, the abstract was read to determine further relevance. If the abstract contained helpful information for answering this review’s objectives, then the article was added to a list for further review. Additionally, any relevant-sounding references found in previously reviewed articles were added to the list.

3.1. Inclusion Criteria

To be selected as relevant or helpful in reaching the objectives of this review, an article must meet the inclusion criteria. Studies were considered eligible for inclusion if they were written in English and used art or art therapy in non-VR or in VR applications, particularly for neurorehabilitation purposes or with implications toward rehabilitating motor impairment. The desired population for inclusion was healthy adults and brain injury patients. Brain injury must refer to an ABI or a TBI for inclusion.

3.2. Exclusion Criteria

Articles with no access to full text were excluded along with review articles. Populations that included patients suffering from disorders, such as cerebral palsy that can be congenital or acquired were excluded as the condition of its occurrence is not always specified. Studies that only measured emotional and mental states were also excluded.

3.3. Study Selection

All articles that matched with the keyword “art” specifically because of the phrases “state of the art” or “state of art” were excluded from the initial search results. Studies published in English were eligible if they used art in a therapy setting, set the intervention in a non-VR or VR environment, used a non-adolescent population of healthy people or brain injury patients, and either focused on neurorehabilitation or had implications for use in neurorehabilitation. Once the list of potentially relevant articles was compiled, each article was read in full and evaluated for relevance by two researchers.

4. Search Results

Using art neurorehabilitation motor virtual “art therapy”, “state of the art”, “state of art” in Google Scholar, 138 results were returned. Of the 138, only 1 article was deemed relevant. To increase search specificity, the following phrase was used in Google Scholar: “allintitle: art neurorehabilitation “state of the art”, “state of art””. From this search, 6 results were returned, and 1 article was used in this review. The phrase “allintitle: art therapy “virtual reality”, “state of the art”, “state of art”” in Google Scholar returned 12 articles, 2 of which are reviewed below. Using the phrase, “(art or “art therapy”) and (neurorehabilitation or “neurological rehabilitation” or “motor rehabilitation”) and “virtual

reality” not “state of the art” in ScienceDirect returned 36 results. Zero of the results were relevant for this review. To reduce the specificity and yield more results, the phrase “art therapy” and (“neurorehabilitation” or “motor rehabilitation”) was used to match with words in the title, abstract, or keywords category. One result was returned but was a duplicate of an article found in the Google Scholar search. Using the phrase “art in neurorehabilitation” and filtering to full text available and non-review article types yielded 13 results from PubMed. Of the 13 results, 0 articles were used. Various other combinations of keywords were used to search the databases, especially Google Scholar as it always returned the largest number of results. The combinations of phrases used in Google Scholar that returned the most relevant articles were as follows: “art in neurorehabilitation”, “art and brain injury”, “art in virtual reality”, and “art therapy and neuroplasticity”. The phrase “state of the art” was used to eliminate many of the results from these searches. Along with the articles collected from the these database searches, relevant articles found within reference lists of the approved articles were used in this systematic review.

4.1. Article Exclusion

Several studies were included in the initial potentially relevant article list but then later removed after reading the abstract or full paper. One example of this is the study conducted by Jones et al. (2019) [25]. The authors conducted a study using art therapy to treat military service members suffering from post-traumatic stress disorder and TBI. The reason for excluding the study is that the focus was on helping the participants understand lingering trauma symptoms and improve communication and quality of life [25]. Another example of an article excluded from the final list of relevant sources is one by Kline (2016) [4]. Kline’s (2016) article, titled “*Art Therapy for Individuals With Traumatic Brain Injury: A Comprehensive Neurorehabilitation-Informed Approach to Treatment*” [4], was excluded for being a literature review-based approach that did not provide experimental data.

4.2. Data Extraction

Nine articles were found to be relevant for evaluating the feasibility of using art therapy for non-adolescent and brain injury patients. Table 1 shows the diversity of the research conducted in the nine studies being reviewed. Once the list of relevant articles was finalized, studies were briefly analyzed to compare similarities and differences for grouping. To more easily display characteristics of the studies, data including population features, art practice used, intervention setting, and results of the studies performed were collected and compiled into three tables: non-VR (Table 2), VR brain injury patients (Table 3), and VR healthy participants (Table 4).

Table 1. Diversity of the reviewed studies.

Author (Year)	Pop Size (Avg Age)	Condition	Setting	Art Medium
Worthen-Chaudhari et al. (2013) [26]	21 (57 ± 18)	motor impaired	non-VR	digital drawing
Bolwerk et al. (2014) [27]	28 (64 ± 4)	healthy	non-VR	mixed media
Paczynski et al. (2017) [28]	5 (84 ± 8)	stroke	VR	3D painting (Splashboard)
Cucca et al. (2018) [29]	20 (45–80) *	Parkinson’s Disease, age-matched healthy	non-VR	mixed media
Kaimal et al. (2019) [30]	20 (45–80) *			
McDonald (2020) [31]	17 (18–65) *	healthy	VR	3D painting (GTB)
Alex et al. (2021) [32]	1 (64–65) *	stroke	non-VR	mixed media
	14 (55–84) *	stroke	VR	mixed media, 3D painting (GTB)

Table 1. Cont.

Author (Year)	Pop Size (Avg Age)	Condition	Setting	Art Medium
Iosa et al. (2021) [33]	4 (60 ± 13)	stroke	VR	2D painting
Hacmun et al. (2021) [34]	7 (42–75) *	expert art therapists	VR	3D painting (GTB)

* denotes age range because average age statistics missing from article. (GTB) is the Google Tilt Brush program built for VR.

Table 2. Summary of studies in non-VR environment.

Author (Year)	Pop Size (Avg Age)	Condition	Art Medium	Results
Worthen-Chaudhari et al. (2013) [26]	21 (57 ± 18)	motor impaired	digital drawing	Interactive art applications are appropriate and helpful in neurorehabilitation
Bolwerk et al. (2014) [27]	28 (64 ± 4)	healthy	mixed media	Art-making promotes improved connectivity in sensorimotor cortex
Cucca et al. (2018) [29]	20 (45–80) * 20 (45–80) *	Parkinson's Disease, age-matched healthy	mixed media	Improvement in impaired visuospatial functions
McDonald (2020) [31]	1 (64–65) *	stroke	mixed media	Art medium and artistic subject matter influenced motor improvement
Alex et al. (2021) [32] (non-VR)	14 (55–84) *	stroke	mixed media	Participants were socially interactive, situated, and reflective

* denotes age range because average age statistics missing from article.

Table 3. Summary of studies using brain injury patients in VR environment.

Author (Year)	Pop Size (Avg Age)	Condition	Art Medium	Results
Alex et al. (2021) [32] (VR)	14 (55–84) *	stroke	3D painting (GTB)	Patients were immersed, physical, and lacked control
Iosa et al. (2021) [33]	4 (60 ± 13)	stroke	2D painting	Significant improvements in art masterpiece group compared to control
Paczynski et al. (2017) [28]	5 (84 ± 8)	stroke	3D painting (Splashboard)	Patients enjoyed art program and showed above average velocities in upper body movement

* denotes age range because average age statistics missing from article. (GTB) is the Google Tilt Brush program built for VR.

Table 4. Summary of studies using healthy participants in VR environment.

Author (Year)	Pop Size (Avg Age)	Condition	Art Medium	Results
Kaimal et al. (2019) [30]	17 (18–65) *	healthy	3D painting (GTB)	Felt in control and free; enjoyed sense of alternate world
Hacmun et al. (2021) [34]	7 (42–75) *	expert art therapists	3D painting (GTB)	Enjoyed experience; user-friendly; felt empowered

* denotes age range because average age statistics missing from article. (GTB) is the Google Tilt Brush program built for VR.

5. Traditional Art Therapy

Transitioning art therapy to neurorehabilitation therapy does not seem like a far stretch. Researchers are already using art therapy to address visuospatial dysfunction and related symptoms of Parkinson's disease [29], analyzing art to detect perspective and preferences of those with limited verbal capabilities [35], and using an interactive art application to provide movement feedback in therapy [26]. With the success of art therapy in treating

mental illness and assisting in physical therapy, implications that art therapy may promote treatment progress and recovery in neurorehabilitation are apparent.

Table 2 shows the extracted data from each of the studies using art therapy in a non-VR setting. A brief summary as well as discussion of results and limitations are included for each study.

5.1. Digital Art Application

Worthen-Chaudhari et al. (2013) conducted a study assessing the feasibility of using an interactive art application in neurorehabilitation therapy [26]. Ranging from 19 to 86 years of age (average 57 ± 18 years), 21 patients suffering from motor impairment and requiring at least 75% assistance on cognitive and motor-related tasks participated in the study. Over 1–7 sessions of their assigned therapy (physical, occupational, or recreational), participants performed movements in the form of drawing in an interactive art application and were able to see their movements in real-time in the form of visual art feedback. The researchers concluded from user feedback and therapists' responses that interactive art applications are appropriate and helpful for use in neurorehabilitation [26].

The results of the feasibility study conducted by Worthen-Chaudhari et al. (2013) have implications on enhancing neurorehabilitation therapy [26]. The interactive art application kept the participants engaged and showed their movements from a different perspective. By seeing visual feedback in the form of art, participants were able to understand their movements. Another implication found from using the interactive art application was that the quality of engagement may allow participants to experience a longer period of flow [26], hence a higher chance of neuroplastic changes. A limitation with this study was the lack of measurable outcomes on performance or improvements. The participants and therapists reported the interactive art application having a positive effect on motor functioning. From this and other feedback provided by the participants and therapists, one can conclude that it is feasible for this type of art application to be used in the neurorehabilitation setting [26]. Any continuing or future work from this study should include an investigation into whether or not this type of interactive art application improves any measurable outcomes of performance or motor impairment.

5.2. Art-Making Changes Brain Connectivity

To investigate how visual art production affects functional connectivity in the brain, Bolwerk et al. (2014) recruited 28 healthy adults, 64 ± 4 years of age, to participate in one of two art interventions: art production or art evaluation [27]. With age, certain areas of the brain begin to lose specialized functioning and turn to alternative brain regions for compensation [36]. Although Bolwerk et al.'s (2014) study investigates several areas of the brain, the focus for this review will be on the sensorimotor cortex because it is involved in motor functioning [10,11,27]. From the results, Bolwerk et al. (2014) found a significant improvement in the intraregional connectivity strength of the sensorimotor cortex with less connectivity in surrounding regions for both groups of participants. However, the art production group yielded stronger changes and stronger connectivity, suggesting a reversal in the loss of specialization and a better improvement in the distinctiveness of the sensorimotor cortex. These results show that art-making promotes improved, efficient interaction between brain regions [27] and holds implications for using art therapy for neurorehabilitating motor impairment.

5.3. Art Therapy for Parkinson's Disease

In Cucca et al.'s (2018) study, 20 patients with Parkinson's Disease (Group 1) and 20 age-matched healthy people (Group 2) underwent 20 sessions of art therapy [29]. The researchers' main goals were to identify general characteristics of visuospatial dysfunction and the impact art therapy has on motor and non-motor symptoms of Parkinson's disease. Using various art mediums, including oils, pastels, clay, watercolor, and paint, participants in both groups completed 9 art therapy projects designed to build in complexity and

focus on different processes of visuospatial functioning [29]. For example, projects 2, 3, 4, and 6 were all created for the purpose of assessing an aspect of motor functioning: physical control, physical and cognitive capacity, fine motor coordination, and perceptions of physical limitations and strengths.

Cucca et al. (2018) found art therapy to be a safe and reproducible rehabilitation practice for Parkinson's disease patients [29]. Due to their results, the researchers theorized that art therapy rehabilitates by either recruiting underlying neural networks of impaired visuospatial functions, similar to action-observation and motor imagery methodologies, or by recruiting compensatory networks associated with targeted visuospatial functions [29]. Both theories have implications for promoting neuroplasticity [9] and neurorehabilitating motor areas of the brain [11]. The results from the study conducted by Bolwerk et al. (2014) seem to follow Cucca et al.'s (2018) first theory of recruiting underlying neural networks and contradict the second theory because the connectivity strength of the compensatory networks in Bolwerk et al. (2014) was reduced after the art-making intervention [27,29]. If Cucca et al.'s (2018) first theory is correct, research on a combined art therapy and motor imagery intervention might yield significantly stronger motor improvement results.

5.4. Personal Journey Back to Mobility

Not many articles exist that discuss measurable outcomes of using art therapy for neurorehabilitation. Most of the studies on art therapy for neurorehabilitation or art therapy in VR are testing for feasibility and usability. McDonald's (2020) own personal experience with art therapy involves using various art forms to rehabilitate her mind and body after suffering a stroke [31]. In her journey back to almost full mobility, McDonald (2020) used a variety of art mediums including paint, charcoal, colored pencils, and water colors. As her mobility improved, she moved on to a harder movement in art-making. Each medium had its own special movement required for proper use, i.e., charcoal on paper required full arm movement and was good for practicing control; colored pencils and brush strokes worked whole hand and wrist extension; and dabbing paint with a paint brush worked the fine motor movements of the fingers and wrist [31]. Along with changing art mediums, the subject matter of the art changed. Art compositions moved from familiar nature scenes to self-portrait style brain-to-muscle pieces. She also began to incorporate visualization of movement or motor imagery into her drawing process. Prior to one of her brain-muscle drawings, an electromyography reading of her deltoid (shoulder) muscle revealed a lack of muscle activation (loss of muscle control). Within days of drawing the brain-to-deltoid muscle connection, McDonald (2020) was able to raise her arm thirty degrees higher. Similar results were seen after incorporating combined brain-muscle and physical activity, such as swimming, running, and smiling, into her artwork [31].

Although it is not a typical experimental study, the results of McDonald's (2020) efforts to perform art therapy on herself further verify how important participation and engagement are in the art activity. Having completed more than thirty types of therapy post-stroke with little to no improvement, McDonald (2020) underwent art therapy and acquired the confidence, enjoyment, and physical goals she desired [31]. One limitation in this self-styled art therapy treatment was that no specific protocol was followed. McDonald (2020) moved through art projects of varying media at her leisure and based her next move off of feelings and observations. Another limitation in her personal journey article was the lack of measurable outcomes from her art therapy. There were, however, several implications to future research and practice involving the subject matter that she used in her art. Once she incorporated visualization or motor imagery and began drawing movements and brain-muscle connections, she started seeing significant improvements in her physical mobility. By the end of her journey in the article, she noted being able to lightly jog and freestyle swim [31]. Motor imagery has already successfully been used for neurorehabilitating motor functioning in brain injury patients [22,37–44]. More research needs to be done to see whether McDonald's (2020) improvements in physical mobility

stem from the subject matter change to brain-muscle connection-based art or from the addition of motor imagery and mental practice to the new subject matter.

Because the article written by Alex et al. (2021) contains one experiment in a non-VR setting and a second experiment in VR, the article was split between Tables 2 and 3, the summary and results will be discussed following Tin in the next section.

6. Art Therapy in Virtual Reality: Brain Injury

This section includes a brief summary of studies consisting of brain injury patients interacting with a virtual art program. Each of the studies contained in Table 3 used stroke patients to observe different aspects of art-making in VR. Some of those include user experience, art content, and range of motion. Investigating these areas of virtual art therapy produced important points that should be considered in future research. Table 3 shows the extracted data from each of the studies using art therapy in a VR setting for brain injury patients, followed by a discussion of results and limitations for each study.

6.1. Traditional Art-Making vs. Virtual Reality Art-Making

Although this article does not focus on neurorehabilitation, it uses brain injury patients to directly compare art therapy interventions in VR to non-VR, and it highlights several important aspects and limitations of performing art therapy in both environments. The main goals of the study conducted by Alex et al. (2021) were to gain a better understanding of the art-making process in a therapeutic setting for stroke patients and to identify potential design opportunities for stroke rehabilitation using art therapy in VR [32]. The researchers observed 14 stroke patients, 55–84 years old, make art traditionally (non-VR) then make it in VR. From their notes and observations, the researchers established the following three themes for comparing traditional (non-virtual) art-making to virtual art-making: artistic subject matter, aesthetics of materials, and art-making process. Figure 2 shows an example of virtual art created by one of the authors of this review using Google's Tilt Brush [45].

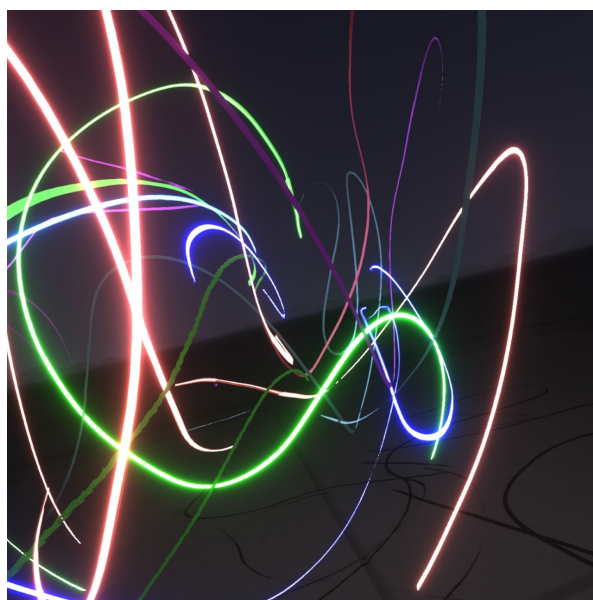


Figure 2. Artwork from virtual art setting.

In the traditional art-making setting, the subject matter mostly consisted of landscapes, portraits, and animals while in the VR setting, the subject matter was described as abstract (random shapes and lines), intentional (specific objects), or emergent (inspired by characteristics of the VR paint) [32]. The artistic subject matter in the traditional setting seemed very intentional with most participants using the familiar as inspiration for their art pieces. The subject matter in the VR setting, however, seemed very fluid and less precise, even with the participants who painted specific objects. The participants' inexperience with VR

and lack of control of the VR controllers could explain why the virtual subject matter came across as more abstract and whimsical.

The aesthetic nature of materials in both settings differed in the art mediums available, the color selection process, and the malleability of the medium. Although the VR system was designed specifically for painting, the traditional setting offered a variety of different mediums, including graphite pencils, paint, watercolor, crayons, colored pencils, rollers, sponges, etc. Another difference was seen in color availability. The traditional setting allowed participants to create their own colors, if not already provided, by mixing paints together. The colors in the VR system were luminescent, seen in Figure 2, and restricted to the participants' abilities to successfully select a desired color from the color wheel or from predetermined color choices displayed in small circles below the color wheel [32]. It was observed that in the VR environment some participants had to ask for assistance in navigating the color picker menu or for help with gauging the depth of an object they wanted to erase [32].

Regarding the final theme, art-making process, used for comparing the two interventions, the participants had opposite approaches for the traditional and VR environments [32]. The participants were very socially interactive with other participants and facilitators in the traditional art setting, but when immersed into the virtual environment, they were more focused on creating art. This is likely due to the group setting of the non-VR environment and the virtual intervention being done individually. Another way that the art-making processes appear to be opposites is in the pace that was used to create the art. In the traditional art environment, the participants were situated and reflective. They made careful decisions before committing something to their artwork by taking the time to identify all their options, reflect upon previous choices, view their artwork from different perspectives, practice with the tools, and use different techniques to apply or shape their chosen medium. In the VR setting, however, the participants were more physical and lacked control. Because the virtual environment provided more space for creating, participants used more of their body in the process and were able to create art all around them instead of just right in front of them. The participants seemed out of control because they were very quick to fill the available space and reported that the controller was not doing what they wanted it to do. It was speculated that the participants did not have comparable control of the VR controllers as they had with the traditional tools and that their lack of control might have been from the mid-air movements draining their physical capabilities [32].

In the traditional setting, the participants worked at tables or desks and were able to rest their arms while they created art [32]. In the virtual environment, the participants engaged more of their upper body in the art-making process. The researchers noticed the wider range of motion used in virtual art-making and hinted towards this increase in physical activity having implications for improving motor impairments in stroke patients. They believe VR offers the unique benefit of allowing for adaptability in the scale of movement translation [32]. Changing the movement scale to translate large movements to smaller brush strokes could encourage more physical movement and lead to greater improvements in physical ability. Alternatively, changing the scale in the opposite direction would allow individuals with smaller or shorter ranges of motion to see their brush strokes covering larger areas, potentially helping to overcome the feeling of being physically impaired. This switch in focus from disability to ability is important in promoting progress and recovery [3,4,46].

There were limitations in the speed at which art was made in the VR environment and in the virtual art program that was used. Participants spent only minutes creating artwork in VR but spent hours creating art in the traditional setting. In the short amount of time the participants were in the virtual environment, they would not have been able to experience the benefits of art therapy, such as Csikszentmihalyi and Csikszentmihalyi's (1992) state of flow [8], or even the same benefits experienced in the traditional setting [32]. Using the same virtual art program, participants from Kaimal et al. (2020) made comments about how

navigating the virtual art environment was easier after they adjusted to the controllers [30]. The groups from both studies were taken through an exploratory session to familiarize themselves with the art software, VR controllers, and virtual environment [30,32]. It is unclear whether the participants from Alex et al.'s (2021) [32] study were finding difficulty in the art program itself or in using the VR controllers. It is clear, however, that they did not use the same careful approach to creating art in the virtual environment as they did in the traditional setting.

From the responses made by the participants and their favoritism towards traditional art-making, it is likely that the participants were overwhelmed by their virtual art-making experience [32]. The VR intervention always took place after the traditional non-VR intervention, and some patients participated in more than one session of the traditional art therapy. It would be interesting to see results from a similar study that compares the same number of sessions and counterbalances the art therapy environments. Another limitation, being in the virtual art program, is present in the interaction between the participants and the art mediums. In the traditional (non-VR) art setting, participants gained a sort of physical connection from being able to touch the art mediums and tools and mix the paints. Part of the art therapy experience is the sensory stimulation that physical materials provide. It is especially important for brain injury patients to experience that sensory stimulation as it is known to enhance awareness and focus [47]. Having one controller in place of various art tools takes away that physical connection that was seen in other studies [29,31]. The resulting gap in feeling connected to virtual art-making caused by this limitation has implications to introducing haptic feedback to virtual art therapy. Iosa et al. (2021) tried to rectify the missing tactile information that comes with virtual environments by adding visual feedback of color and shadow to the virtual tool used in their VR program [33].

6.2. Art Improves Performance in Virtual Reality

Iosa et al. (2021) conducted two experiments, but the first was excluded due to the population used. In the second experiment, four (4) stroke patients with an average age of 60 ± 13 years performed four (4) sessions of virtually interacting with either an art masterpiece or a piece of control art [33]. The virtual art system consisted of a 2D canvas covered in a white film. Using the VR controller, participants were to "paint" over the canvas, revealing either an art masterpiece or the control art. The illusion of painting was provided by the white film disappearing when the virtual art tool came into contact with the canvas. To add visual feedback to the system, the virtual art tool (a sphere) would turn green when in contact with the canvas but would turn red when the participant moved beyond the canvas. The movement of the virtual sphere and participant's hand were tracked and recorded for performance measures during the sessions. The two participants who interacted with the art masterpiece had significant improvements for all computed parameters compared to the two participants who were assigned the control artwork. The participants also reported high scores of usability for the virtual reality task, hinting at implications of future use for VR-based rehabilitation. Limitations include small sample size and differences in details of the art masterpieces used [33]. Some of the art masterpieces contained humans while others consisted of fluid nature scenes. Artistic subject matter used in art therapy needs to be further studied, as it seems to have made an impact in three of the five studies reviewed so far [31–33]. There are implications that if art therapy can be performed while the brain is monitored using an electroencephalogram (EEG), then certain details and aspects of artwork, such as landscapes versus people in motion, can be used to target specific areas of the brain for rehabilitation [33].

6.3. Digital Art Program in Virtual Reality

Paczynski et al. (2017) studied the interaction between elderly people and an art program designed for creating digital artwork in VR [28]. Fifteen older adults, ranging from 69 to 96 years of age (average 84 ± 8 years), living in an aged-care facility took turns using the digital art system for six weeks. On average, the participants engaged

in four 11.6 min sessions where they were free to create art without trying to reach a specific goal. Right and left hand movement was tracked along with lower body movement to show changes in performance. To analyze how their digital art program impacted movement, cognitive stimulation, and creativity, Paczynski et al. (2017) separated the participants into the following categories of impairment: stroke, dementia or memory impairment, and depression [28]. For the purpose of this systematic review, only the stroke and dementia groups' results will be discussed. For the five participants affected by stroke, all showed above average velocities and upper body movements. The majority of the stroke participants enjoyed interacting with the digital art program and felt a positive impact on their physical and cognitive states. The art program allowed for the stroke participants to express themselves creatively, despite their mental or physical impairments. For the group of participants suffering from dementia or memory impairment, four of the nine felt a positive impact on their cognitive health, and five of the nine felt a positive impact on their physical health. Data results for movement and creativity were not provided for this group [28].

Paczynski et al.'s (2017) results revealed that art in VR can be enticing and flexible for many types of users if they can stay engaged long enough to reap the benefits. A trend of growing indifference toward the art program can be seen from the recorded distances of the hands and lower body traveled in the first sessions compared to those traveled in the final sessions. Having seven participants who traveled furthest in their first session implies that the novelty of the art system and the initial excitement and engagement provided a strong motivation for interaction that appears to have slowly faded [28]. If an aspect of sensory stimulation were added to the digital art program, attention might have been more easily sustained [47]. Adding a goal or theme of subject matter to create also might entice participants to stay motivated over several sessions of use. Having only six participants complete four or more sessions raises the question of whether those six were able to reach the state of flow easier than the other participants or if they were the only six to reach the state of flow. The virtual art program presented in Paczynski et al. (2017) afforded accessibility to a creative outlet for multiple disabilities that otherwise might not be able to express themselves [28]. There are implications to cognitive motor repair in the results of the participants who saw an increase in average velocity of one or more body parts. Because this study was for learning about interaction between participants and technology, any future work should investigate if the increased velocity was due to improved motor functioning or due to the excitement created by the new art program.

7. Art Therapy in Virtual Reality: Healthy

A summary and discussion of results and limitations are included for each study. The two studies being reviewed in this section used healthy participants in virtual art making to examine user experience and interaction with the same virtual art program. Based on the reports from both groups of participants, it is noticeable that the healthy participants had an easier time navigating the virtual art program than the brain injury participants. Table 4 summarizes the data extracted from each study of the studies that used art therapy in a VR setting for healthy people. ¶

7.1. Experiencing Art Therapy in Virtual Reality

The study performed by Kaimal et al. (2020) was included because of its implications toward using the specified art therapy system on individuals with motor impairment. Kaimal et al. (2020) studied 17 individuals, aged 18–65 years old, to gain an understanding of their experiences with art therapy in VR from one free-form art-making session [30]. From the feedback provided by the participants, the researchers identified key aspects art therapy in VR offers that traditional art-making does not. Creating art in the virtual environment engaged full body movements, which the participants found to be enjoyable. Being able to erase part of the artwork eased the sense of permanence typically associated with traditional art mediums. Participants did not have to worry about making mistakes

and instead were able to focus on exploration and creative expression [30]. Many participants noted that once they familiarized themselves with the controllers, they felt in control and were able to feel the art flow from them without any distractions. They also expressed their enjoyment in the feeling of being transported to an alternative or imagined space away from the constraints, pressure, and stress of the real world [30].

A practical implication that can be drawn from Kaimal et al.'s (2020) study includes using virtual art therapy on individuals lacking fine motor skills [30]. Experimental limitations are seen more from the system used rather than the virtual environment. The art program does not allow for changing colors of the environment or background, and the art tools sometimes came across as the clunky version of traditional tools [30]. Similar comments were made by the participants in Alex et al.'s (2021) study [32]. Although Kaimal et al. (2020) and Alex et al. (2021) used the same art software in VR, they yielded conflicting results. The population in Kaimal et al.'s (2020) study consisted of younger healthy people [30] while Alex et al.'s (2021) study consisted of elderly stroke patients [32]. The younger population reported more enjoyment in regards to art therapy in VR and did not seem to have as much trouble navigating the menus or using the controller(s) [30]. Another difference is the approach to art-making in the virtual environment. The elderly stroke population seemed overwhelmed by their lack of control of the controller and rushed through creating an art piece [32]. The younger, healthy population seemed to take the time to master the controller and move through the space during the creating process to view their artwork from different perspectives [30]. It is unclear if the participants from Alex et al.'s (2021) [32] study underwent the VR intervention on the same day as their last non-VR art therapy session, but, if so, that could have influenced the quick pace seen from those participants in the VR session.

7.2. Expert Art Therapists on Art Therapy in Virtual Reality

To examine the potential for art therapy in VR, Hacmun et al. (2021) had seven expert art therapists, 42–75 years old, observe art-making and create their own art in a virtual environment [34]. Each participant was introduced to the VR medium prior to the creation and observation sessions. In the creation session, participants were allowed to make 3D art in a 360-degree space. In the observation session, participants simultaneously watched the creator in the real-world environment and viewed the virtual art on a computer screen. In the results from the study, the researchers found that most of the participants were surprised by how much they enjoyed creating art in VR and how user-friendly they found the medium. Participants reported missing the physical contact that traditional art-making provides but described the ability to freely move through the art as fun and unique. Some participants noted that they felt their body's physical movement to be a sort of tactile feedback even though there was a lack of physical substrate in the art created. All of the participants reported that VR was suitable for art therapy, but some stated that it should be used along with other creative media. Most of the participants agreed that the ideal population for using art therapy in VR is adolescents who are already familiar with and attached to technology and screens. They reported that they were unsure whether VR could be beneficial to the elderly or physically disabled [34].

Hacmun et al. (2021) point out that a big limitation in their study is that the participants mainly consisted of digital immigrants who do not consider themselves to be technologically savvy [34]. Another limitation that the authors mention is the participants only performed one session of creating art in VR. They acknowledge that feedback from the art therapy experts might change with more practice and familiarization with the VR medium. In terms of movement during virtual art-making, the participants spoke a lot about the freeing feeling of using their whole body to create art but did not connect this feeling of embodied expression with implications toward motor neurorehabilitation or even physical rehabilitation. However, the researchers associate the participants' reporting on movement with results from other studies that have shown movement enhances the feeling of being present in VR due to the increase in connection between the real and virtual

worlds [34]. Having the connection between reality and VR can provide an alternative point of view for patients to establish a new sense of self or self-awareness [4,15].

8. Discussion

Brain injuries remain a serious public health concern and leave many individuals with long-lasting disabilities. Attempts to create new, innovative ways of using art therapy to treat and repair disabilities caused by brain injury have been made and show promising results in multiple areas of therapy [15,25,35,46,48] with implications toward using art therapy in neurorehabilitation practices [1,10,49–51]. When using art therapy for motor neurorehabilitation, especially for brain injuries, promoting brain plasticity needs to be considered. Neuroplastic changes of motor areas in the brain are thought to happen from a variety of stimuli, including: creative state of flow [9], subject matter [8], motor imagery, action observation, and action execution [22].

In answering the first research question, consider the results from the studies that were reviewed, see Figure 3. Bolwerk et al. (2014) showed that the process of art-making significantly improves intraregional connectivity strength in the sensorimotor cortex [27], which holds implications for using art therapy for motor neurorehabilitation. With the positive improvements in motor functioning seen from Worthen-Chaudhari et al. (2003) and Paczynski et al. (2017), it seems feasible that art therapy can be used for neurorehabilitation purposes outside VR [26,29] and inside VR [28] for patients suffering from brain injury. Hacmun et al. (2021) revealed that the freedom of movement offered in VR can help establish the connection between the real and virtual worlds [34], which can provide an alternative point of view for patients to establish a new sense of self or self-awareness [4,15].

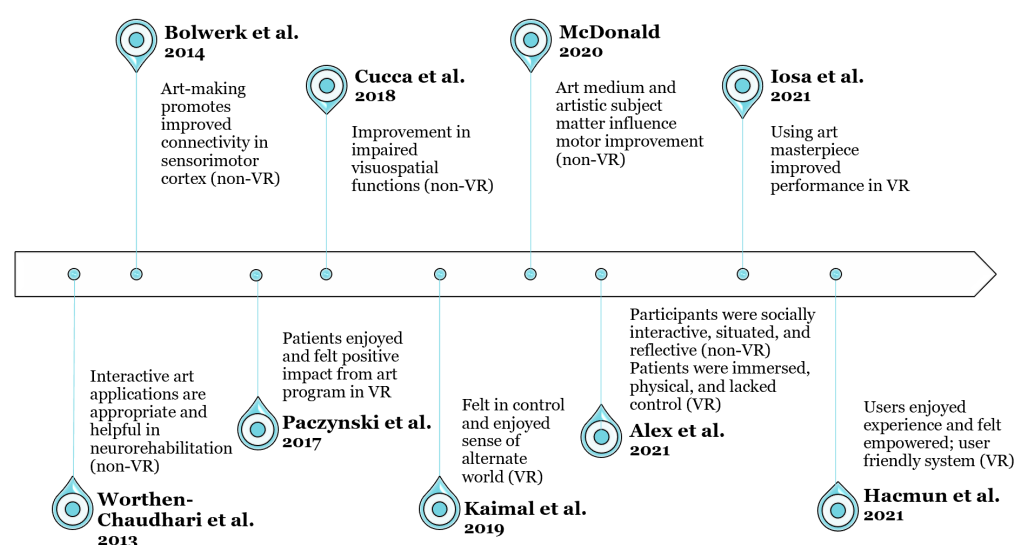


Figure 3. Timeline of study contributions.

McDonald (2020) performed art therapy in a traditional (non-VR) setting and began seeing significant improvements in her physical mobility once the artistic subject matter changed to brain-muscle connections and movement visualization was added [31]. From these results, though, the question is raised of whether it was the physical art-making or the combination of subject matter and movement visualization (motor imagery) that improved her motor functioning. If the answer is the latter, then those aspects of art therapy can easily be transferred to a virtual environment. Many researchers are already successfully using motor imagery for neurorehabilitation in VR [22,37,39,42,44]. If the answer is the former (physical art-making), such as that seen in the results from Cuca et al. (2018) [29], then the physical contact and skill required of specific art mediums might play a more significant role in rehabilitation and should be incorporated into virtual art therapy programs in the form of haptic feedback [20,34]. If it turns out to be due to a combination of art-making

and subject matter or motor imagery, then the results from Iosa et al. (2021) show that it is possible to yield motor improvements, based on subject matter, in a virtual setting [33]. Although further research into artistic subject matter and combining art therapy with motor imagery needs to be conducted, it is evident that using art therapy in VR for rehabilitating motor functioning is feasible.

Looking at the studies performed by Alex et al. (2021), Kaimal et al. (2020), and Hacmun et al. (2021), they all used the same VR art program on different populations but yielded varying results and limitations [30,32,34]. The elderly stroke population, though seated in a swivel chair, were quick and chaotic in filling the available space [32] while the younger, healthy population was slow and deliberate with their actions and placements [30]. It can be inferred that the physical limitations of the stroke patients affected their control when having to hold the VR controller in mid-air to paint [32]. Additionally, there likely is a limitation in the older, stroke group being confined to a swivel chair [32] while the two healthy groups were free to walk around the space [30,34]. To attain the freedom to create art in VR using full body movements, like those seen in healthy participants, the available population of brain injury patients would have to be reduced to the physically impaired of a certain degree. Unless a mobility support system is used in conjunction with VR or an alternative way of making art in VR is created, it is unsafe to allow patients, specifically with lower limb impairments, to physically move freely around the virtual environment.

A recurring theme appears in several of the studies that were reviewed. Patients seem to quickly lose engagement when art therapy is performed outside of the traditional setting [26,28,32]. It can be deduced that the participants in Iosa et al.'s (2021) study did not lose interest in the VR art task because of the added visual feedback on the virtual art tool [33]. Adding visual feedback follows the idea that sensory stimulation is engaging and draws focus to the task at hand [47]. Following the same principle, switching from traditional art mediums and tools to a VR controller causes a disconnect between the user and the art-making process. Haptic feedback has the potential to recreate a physical connection between user and art medium or tool in a virtual environment. The participant groups from Alex et al. (2021) and Hacmun et al. (2021) agreed on the missing physical connection to art mediums in VR. However, the group from Hacmun et al.'s (2021) study reported the virtual art program to be user-friendly [34] while the group from Alex et al.'s (2021) study seemed to struggle using the program [32]. Because the two healthy populations had an easier time using the virtual art program than the stroke population, future studies should allow brain injury patients extra time or practice sessions to familiarize themselves with navigating virtual art applications and VR controllers. In addition to balancing the learning curve, implementing alternative modalities of controlling virtual art programs has the potential to establish the missing connection between user and virtual art mediums. Adding that kind of sensory stimulation to virtual art programs might also be effective in helping brain injury patients gain control inside the virtual environment. Comparing the reviewed studies, most of the limitations and differences appear to stem from the experimental design(s) or the virtual art system used rather than from the virtual environment [26,28,30,32,34]. If adjustments can be made to the virtual art software, interactivity of materials, and experimental design to ensure a more usable, accessible, and stimulating VR experience, then there is a high probability that brain injury patients can enter the state of flow and induce neuroplasticity, making it feasible to use art therapy in VR for neurorehabilitation. Future work in virtual art therapy will need to assess the correlation between performance and artistic subject matter, as well as overcome the lack of measurable outcomes for showing performance and motor improvements. Utilizing mobility tests for pre and post study measurements, such as the Functional Independence MeasureTM [26] and the Fugl-Meyer assessment [52] conducted to assess patients for inclusion criteria, is a way of reducing heterogeneity and allowing for comparable results between studies. Another way of producing measurable outcomes is by combining EEG and art therapy. Using EEG during art therapy could reveal how artistic subject matter influences activation in certain brain areas and promotes use-dependent plasticity [9,33]

by studying power levels in different brain regions. It also presents a way for measuring neuroplastic changes [51]. In their study of surveying cortical activation patterns after making art and after performing a physical task, King et al. (2017) revealed a statistically significant difference in cortical activation after art-making compared to baseline data. Their findings have implications toward being able to produce measurable outcomes from art therapy used in neurorehabilitation [51].

9. Conclusions

The systematic review conducted in this paper defined the terms of feasibly using art therapy in VR for the motor neurorehabilitation of brain injury patients and outlined the need for future research to use post-study assessments to reduce the heterogeneity of results. Although limitations exist, researchers are continually finding ways to advance the use of art therapy in VR. More research involving multiple sessions of art therapy in VR needs to be conducted to study the learnability and usability of virtual art programs. With further research into artistic subject matter and sensory stimulation in virtual art applications, approaches to art therapy in VR can be fine-tuned for targeting and rehabilitating motor areas of the brain to achieve results similar to those observed in more traditional art therapies.

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