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Post COVID-19 Cognitive disorders: Virtual Reality and Augmented Reality as mental healthcare tools

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Abstract. Some time ago Virtual Reality and Augmented Reality were exclusively devoted to the gaming industry. Nowadays, both technologies are experiencing a deep interest from various spheres, including healthcare sector.
The new infectious disease COVID-19 has had a catastrophic effect on the world's demographics. Many patients with mild or severe COVID-19 do not recover completely and present with a wide variety of chronic symptoms after infection, often of a neurological, cognitive or psychiatric nature. The most common signs of cognitive disorder can be summarized as *mental fog*, *memory* problems and *concentration* problems.
The aim of this study was to analyze the opportunities for Virtual and Augmented Reality in the cognitive interventions related to mentioned disorders by searching for articles in scientific databases. We conclude that as these technologies and devices become cheaper and accessible worldwide, can at least be regarded as a rehabilitation therapy as effective as traditional training, and to some extent better than it.

Keywords: COVID-19, Mental Health, Cognitive Disorders, Virtual Reality, Augmented Reality.

1 Introduction

Virtual Reality (VR) and *Augmented Reality* (AR) systems are currently understood as entertainment tools, used for watching movies, playing video games, and even to immerse oneself into the digital Non-Fungible Tokens (NFT) market. Virtual reality gives people a hands-on experience of just about anything. It has not just moved the imagination of science-fiction fans, but also clinical researchers and real-life medical practitioners.

The healthcare sector is an area with fascinating possibilities. It is one of the early adopters of VR/AR and is making the most out of it. The launch of Oculus Rift and HTC Vive has further augmented the usage of Virtual Reality and

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Augmented Reality [1, 2]. They triggered a huge increase in the use of VR/AR in the healthcare sector which continues to be fascinated y impressed by the diverse potential applications.

There are increasingly great examples of VR/AR having a positive effect on patients' lives and physicians' work. From developing new life-saving techniques to training the doctors of the future, VR/AR have a multitude of applications for health and healthcare, from the clinical to the consumer. At this time, the key application areas of VR/AR in healthcare are *medical training*, *patient treatment*, *medical marketing* and *disease awareness* [3, 4].

Treating Mental Health Issues like anxiety, panic attacks, and other mind-related issues such as phobias are great examples of medical patient treatment VR/AR transforming patient lives. Usually, patients are immersed in a safe and controlled environment and confronted with their fears recreated virtually. In more complicated situations such as Post-Traumatic Stress Disorder (PTSD), the Virtual Reality Exposure Therapy (VRET) technology has yielded positive results, giving patients another chance at life [5, 6].

The COVID-19 pandemic worsened the suffering of people with mental and physical ailments. The healthcare system has never been pit against an enemy such as COVID-19, forcing us to look for innovative solutions that make global healthcare more flexible and future-ready for such disruptions. Global healthcare is turning to VR/AR, which certainly make for a lucrative prospect for the future. They are helping in better preparing the healthcare systems for pandemics and global health crises, such as the one we face now [7]. And while other industries are jumping on the VR wagon, hospitals, medical institutions, and healthcare tech companies are adapting to VR space equally well [8].

Research in past epidemics has revealed a deep and wide range of psychosocial consequences at the individual and community levels during outbreaks. There are multiple associated psychological disturbances, ranging from isolated symptoms to complex disorders with marked impairment of functionality, such as insomnia, anxiety, depression, and post-traumatic stress disorder. Therefore, it is necessary for mental health services to develop strategies that allow them to react with skill and to achieve support for health personnel and the affected population, in order to reduce the development of psychological impacts and psychiatric symptoms.

In this way, the aim of this paper is to analyze and classify the use of new technologies as a therapeutic element in cognitive disorders. The work will review existing systems and applications about VR and AR technologies to achieve telerehabilitation. Research will focus on assessed applications that enhance cognitive rehabilitation interventions for sequels caused by COVID-19.

Section 2 details some statistics on post COVID-19 symptoms and lists the signs associated with cognitive disorders. Section 3 presents the benefits of applying alternative realities in cognitive therapies. Section 4 gives a brief overview of existing applications and how they can be used for the treatment of cognitive disorders according to the cognitive signs detected. Section 5 provides a small discussion and future guidelines.

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2 Post Covid-19 Symptoms

Since December 2019, COVID-19 has rapidly spread worldwide, affecting people in 210 countries and territories with the current tally exceeding 200 million infected people and more than 4,265,903 deaths [9].

In December 2020, the UK National Institute for Health and Care Excellence (NICE) published guidance on the long-term consequences of COVID-19. This guidance distinguishes between *acute COVID-19* (signs and symptoms of COVID-19 last up to 4 weeks), *ongoing symptomatic COVID-19* (signs and symptoms of COVID-19 are 4 to 12 weeks in duration), and *post COVID-19* syndrome. NICE guidance defines post COVID-19 syndrome as the cluster of signs and symptoms that develop during or after a COVID-19-compatible infection, continue for more than 12 weeks, and are not explained by an alternative diagnosis. Symptoms can often occur overlapping, and fluctuate and change over time, sometimes in a flare-like fashion, and affect any body system, including cardiovascular, respiratory, gastrointestinal, neurological, musculoskeletal, metabolic, renal, dermatological, ENT (Ear, Nose and Throat Infections), and hematologic systems, in addition to psychiatric problems, generalized pain, fatigue, and persistent fever.

Seventy-six percent of those affected reported at least one symptom during follow-up and a higher percentage of prolonged symptoms was observed in patients aged 40 to 60 years and those who were hospitalized. The most common symptoms after discharge were fatigue or muscle weakness (63%) and sleeping difficulties (26%). Anxiety or depression was also reported in 23% of affected people. Studies on psychological sequelae show that almost 7 out of 10 (64.4%) of the participants reported cognitive failures (mild, moderate and severe). Half (46.3%) responded that their attention worsened and more than 4 out of 10 (43.1%) also reported that their memory worsened after being infected with COVID-19 [10, 11].

Cognitive disorders are a category of neurological disorders [12, 13]. Cognitive disorders are defined as any disorder that significantly impairs the cognitive function of an individual to the point where normal functioning in society is impossible without treatment. They primarily affect cognitive abilities including, learning, memory, perception, and problem-solving.

Cognitive disorder signs vary according to the particular disorder, but some common signs and symptoms overlap in most disorders. The most common signs of cognitive disorder can be summarized as *Mental fog*, *Memory problems* and *Concentration problems*.

- **Mental Fog**. Clouding of consciousness (also known as brain fog or mental fog) is when a person is slightly less wakeful or aware than normal. They are not as aware of time or their surroundings and find it difficult to pay attention. Typical symptoms of brain fog include poor concentration, an extra effort to focus on a task, trouble multitasking or managing too many tasks at once and trouble tracking what you are doing.
- **Memory Problems**. Memory loss can be defined as pathological forgetting: to learn something new, to recover memories from the past, or to remember

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specific events. When we forget something, it is not usually that we "lose" the memory itself, but that our brain "can't find its way" to the memory we are trying to find. Our brain engages different structures to work with different types of memory. The main memory modalities are: *short-term* memory and *long-term* memory.

– **Concentration Problems**. Concentration difficulty is a decreased ability to focus your thoughts on something. Concentration difficulties can be related to difficulty staying awake, impulsiveness, intrusive thoughts or concerns, overactivity, or inattention.

The factors that have proven to be most effective in preventing and treating cognitive disorders are: *adequate sleep*, a *good diet*, *physical exercise*, an *active social life* and *cognitive activities*. The brain acts much like our muscles, so the more we use it, the better shape it will be in. **Cognitive Stimulation** seeks to stimulate, train and strengthen the different cognitive abilities of people, such as attention, perception, memory, language and executive functions.

Although the signs of cognitive impairment mentioned above are clearly different, the treatment of some of them can be addressed together. For example, for mental fog and memory problems cognitive stimulation through games, everyday tasks, and memory exercises is recommended. For concentration problems, arithmetic exercises, try to number, word search puzzles, memorizing images, among others are recommended.

3 Alternative Technologies in Cognitive Therapies

Cognitive rehabilitation encompasses a wide range of therapeutic cognitive interventions to achieve functional changes by reinforcing, strengthening, or reestablishing previously learned patterns of behavior or establishing new patterns of cognitive activity or mechanisms to compensate for impaired neurological systems.

These interventions are based on psychological theories and models of behavior and behavioral change and on neuropsychological models of brain–behavior interactions, and for many years can be conducted with paper–pencil tools, social skills training, physics skills training, cognitive rehabilitation and psychostimulant medication in some cases.

Related to this kind of therapies, many scientists suggest that it is an inadequate form of intervention. The main reasons are as follows: stimulants do not work for all people and the psychostimulant effects are limited to the period in which the drugs are physiologically active. On the other hand, some studies have shown that in order to improve functioning, interventions should include training of more specific daily-life skills and compensatory strategies. Another critical barrier for effective treatment is a lack of motivation in the patients to participate in the assigned training despite receiving encouragement and support. Perhaps because of these problems with limited transfer and motivation, attrition rates are often high in cognitive rehabilitation programmes.

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In this context, it has been proven that training/therapy based on virtual and augmented technologies is feasible to accommodate these problems because of its highly engaging and gamified format. Virtual reality can be defined as a naturalistic simulated environment with which the user can interact as if the user was present. With the possibility for a fully controlled and safe environment the technology offers a more ecological valid environment for cognitive rehabilitation as it enables a multimodal setting that is quite similar to situations that patients might encounter in their daily lives. Thus, cognitive training can be integrated more easily with daily life functioning. On the other hand, AR is the integration of digital and physical information in real-time that allows the user interaction with a virtual and real world. These emerging technologies are a great promise because they motivate people with new challenges; providing rapid feedback that is tailored to their specific interests and individual needs.

4 Applications

As stated above, the signs and symptoms of COVID-19 cognitive impairment overlap in most disorders. Therefore, existing VR/AR applications can be classified into two main groups: applications that address Attention and Concentration problems; and applications that address Mental Fog and Memory problems. Figures 1 and 2 show a diagram of the systems surveyed, specifying the authors, year of implementation, purpose of the application, technology used and name of the system (if any).

4.1 Mental Fog and Memory systems

The applications include systems that were originally developed for specific diseases (such as Alzheimer's, Epilepsy, Dementia, Traumatic Brain Injury) and that are able to improve memory skills. Most of these applications are concerned with enhancing the processes of encoding, storage and recovery of information. In certain cases it has been a common practice to use external aids to promote memory, such as assistants, diaries, alarms, etc. [14–33].

4.2 Attention and Concentration Systems

The main objectives of medical intervention programs are to increase attentional capacity, decrease response time, reduce the phenomenon of hemineglect, and improve various components of the attentional system, such as sustained, selective, alternating or divided attention. The most commonly treated cases are *Attention Deficit Hyperactivity Disorder* (ADHD) and *Autism Spectrum Disorder* (ASD). In the 1990s, these programs began to include alternative technologies such as virtual reality and augmented reality in their therapies. Nowadays, it is no longer an inclusion but rather of computer-based cognitive therapy such as the following virtual/augmented reality-based cognitive rehabilitation systems [34–57].

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VIRTUAL REALITY				
Authors	**Year**	**Aim**	**Technology**	**Name**
W. H. Guo et al. [14]	2004	Memory deficits	HMD	-
Veronika Brezinka [15]	2011	Cognitive-behavioural	Web	Treasure Hunt
Emmanuelle Chapoulie et al. [16]	2014	Reminiscence	Immersive IBR	IVIRAGE
Monthon Intraraprasit et al. [17]	2017	Cognitive impairment	HMD	-
Fernando A. Chicaiza et al. [18]	2018	Memory loss	HMD	-
Kiran Ijaz et al. [19]	2019	Predementia	HMD	VR-CogAssess
Andrea Vitali et al. [20]	2021	Memory loss	HMD	-
AUGMENTED REALITY				
Authors	**Year**	**Aim**	**Technology**	**Name**
S. Wood et al. [21]	2012	Memory loss	Mobile App	TARDIS
Eduardo Quintana et al. [22]	2012	Alzheimers	Mobile App	ANS
M. Carmen Juan et al. [23]	2014	Spatial memory	Mobile App	ARSM
Oscar Rosello et al. [24]	2016	Memorization	Mobile App, Headset	NeverMind
Mat Masir et al. [25]	2016	Dementia	AR Desktop	DARD
Costas Boletsis et al. [26]	2016	Dementia	Mobile App	CogARC
Leah Gilbert et al. [27]	2017	Memory impairment	Mobile App	-
Dennis Wolf et al. [28]	2018	Dementia	Mobile App, HMD	cARe
Keynes Masayoski et al. [29]	2018	Alzheimers	Mobile App	-
F. Munoz-Montoya et al. [30]	2019	Spatial memory	Mobile App	-
Jonne Schoneveld [31]	2020	Dementia	Mobile App	-
Arezou Niknam [32]	2021	Spatial Memory	Mobile App	-
Rui Silva et al. [33]	2021	Cognitive Therapy	Mobile App	SAR-ACT

Fig. 1: Mental Fog and Memory systems.

VIRTUAL REALITY				
Authors	**Year**	**Aim**	**Technology**	**Name**
Joan Mc. Comas et al. [34]	2002	ADHD	PC (3 displays)	-
N. Yan, Jue Wang et al. [35]	2008	ADHD	VR-integrated	IVA-CPT
Meghan Elizabeth Huber [36]	2008	Hemiplegia	PS3	-
Shih-Ching Yeh [37]	2012	ADHD	HMD	-
Silvia Erika Kober et al. [38]	2013	Spatial disorientation	PC, Joystick, Mic	-
Pierre Nolin [39]	2016	ADHD	HMD	ClinicaVR
Kim C M Bul [40]	2016	ADHD	PC	-
Jofre et al. [41]	2018	Attention motivating	Kinect, PC/CAVE	-
Maria Cristina Barba [42]	2019	ADHD	Kinect, HMD, EEG	BRAVO
Manish Kumar Jha [43]	2020	Alzheimer's disease	HMD	-
XRHealth [44]	2020	ADHD	HMD	XRHealth
AUGMENTED REALITY				
Authors	**Year**	**Aim**	**Technology**	**Name**
Mohd Azmidi Abdullah et al. [45]	2012	ADHD Kids	PC, webcam	ADHD-Edu
Lizbeth Escobedo [46]	2014	Attention disorientation	Mobile App	Mobis
Hendrys Tobar-Muñoz et al. [47]	2014	ADHD	PC, webcam	Gremlings
Jorge Bacca [48]	2015	Learning motivation	Mobile App	-
Chien-Yu Lin et al. [49]	2016	ADHD	Mobile App	MAR
Martín Sabarís [50]	2017	Down syndrome	Mobile App	-
I-Jui Lee et al. [51]	2018	ASD kids	PC, webcam	AR-RPG
Diego Avila-Pesantez et al. [52]	2018	ADHD kids	Mobile App	ATHYNOS
Eleni Mangina et al. [53]	2018	ADHD	Mobile App	AHA
Maria Cristina Barba et al. [42]	2019	ADHD	Kinect, HMD, EEG	BRAVO
Tasneem Khan et al. [54]	2019	Learning motivation	Mobile App	-
Saad Alqithami et al. [55]	2020	ADHD	HoloLens	AR-Therapist
Neha U. Keshav et al. [56]	2019	ADHD	HoloLens	D. Attention-Related AR
Katherine Wang et al. [57]	2020	Attention disorientation	Mobile App	MARA

Fig. 2: Attention and Concentration Systems.

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5 Discussion and Conclusions

This section briefly analyzes the works surveyed in terms of the use of VR and AR technologies as therapeutic tools in the treatment of the cognitive disorders addressed and outlines some conclusions to be taken into consideration for future works.

The launch of Oculus Rift and HTC Vive, together with the emergence of smartphones, enabled access to technology with great potential for VR and AR developments. As a consequence, it triggered a boom in all kinds of research related to these technologies. Additionally, the current pandemic has forced many treatments to be performed by telehealth, further encouraging developments that use everyday devices instead of complex VR and AR devices.

Regarding the use of AR technology, both for concentration and memory, AR appears to be a more recent area of research. It was initially supported by notebooks and webcams and then became strongly dominated by the use of smartphones. Smartphones are currently the main device used in AR applications. In particular, for memory problems, implementations focus on AR over VR in line with the study by Niknam which suggests that using AR is better than VR for cognitive applications to enhance spatial working and long-term memory [32].

Regarding the use of VR technology, there is evidence of work carried out since the 1990s, both for its application to concentration and memory problems. Therefore, VR is a very robust field. In the last decades a significant growth of immersive systems using VR headsets with smartphones has been reported.

Concluding, 45 articles and texts have been included, which showed a relationship between VR, AR, and the investigated disorders. Of the included articles, 33 involved evaluations with patients, and all of them proposed their systems as therapeutic alternatives. Articles not providing additional information for the purposes of this work, as well as those more than 20 years old, were excluded.

Healthcare professionals suggested that rehabilitation therapy based on VR and AR technologies are likely more effective than conventional therapy. On the other hand, it should be noted that there is still a lot of work to be done in terms of optimization and availability of the applications surveyed. Furthermore, there is a growing number of doctors who are turning to VR for treatments for phobia, surgery simulations, skills training, etc.

A lot of the applications mentioned above are still in their infancy. In the coming years, VR/AR will be used more and more to improve the accuracy & effectiveness of current procedures, and enhance the capabilities of the human being, both as the care-giver and the patient. Quite simply, the potential for VR in the healthcare sector is huge, limited only by the creativity & ingenuity of those creating and applying the technology. However, experts predict that AR will gain greater traction in the sector in the years to come.

In a pandemic context, the global demand for medical needs over the internet sets the stage for virtual reality to step up and claim what has been long pending: a completely immersive, sensitive VR healthcare experience.

Finally, we believe that as VR/AR technologies and devices become cheaper and accessible worldwide, these technologies can at least be regarded as a rehabilitation therapy as effective as traditional training, and to some extent better than it.

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