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The Effectiveness of Cognitive Rehabilitation in Improving Working Memory and Attention in Acute COVID-19 Survivors

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Abstract

Background: *This study aimed to determine the effectiveness of cognitive rehabilitation in improving working memory and attention in acute COVID-19 survivors.*
Methods: *The current study utilized a quasi-experimental design with a Pre-test Post-test, and a control group. The target population consisted of all individuals suffering from acute COVID-19 in the city of Tehran. From this target population, 36 individuals were selected using purposive sampling. These 36 individuals were randomly assigned to two groups of 18, experimental and control. Assessments were conducted on the participants before and after the intervention. The experimental group received the RehaCom cognitive rehabilitation, while the control group did not receive any intervention. The data collection instruments were tests of working memory, selective attention, and divided attention from the RehaCom cognitive rehabilitation software. Data analysis was done using multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA) with SPSS26 software. The significant level was set at 0.05.*
Results: *The findings showed that there was no significant difference in working memory between the experimental and control groups (P-value<0.05). Additionally, no significant difference was observed in the subscales of reaction speed and visual divided attention between the experimental and control groups. However, there was a significant difference in the subscales of auditory divided attention and reaction control between the experimental and control groups (P-value<0.05).*
Conclusions: *Considering the means of research variables in the Post-test stage, it can be concluded that cognitive rehabilitation can improve reaction control and auditory divided attention in acute COVID-19 survivors.*

Keywords: Cognitive rehabilitation, Working memory, Attention, Severe COVID-19.
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Introduction

COVID-19, first reported in Wuhan, China, is a severe acute respiratory syndrome that spread to other areas of China and then worldwide. The symptoms of this disease include respiratory problems, decreased oxygen levels, shortness of breath, dry and irritating coughs, throat irritation, mucus, and the risk of pulmonary fibrosis[1]. Most patients with COVID-19 have mild symptoms, and in 14% of cases, the infected individual exhibits severe symptoms, including pneumonia and shortness of breath. Also, in 5% of cases, the patient's condition worsens toward respiratory failure, septic shock, and organ failure. After recovering from the initial illness, individuals with COVID-19 experience memory, attention, and concentration problems[2]. Patients with COVID-19 typically experience cognitive issues, with one of these cognitive problems being a deficit in executive functions [3].

In 61 studies focusing on persistent symptoms in recovered patients, several areas were identified as persistent symptoms, including fatigue, respiratory, motor, and psychological symptoms being among the most important4. Little research has been done on the impact of COVID-19 on the brain, and conflicting findings have been reported. Neuroimaging of patients with COVID-19 in the acute and subacute phases shows that about one-third of them show brain abnormalities, including an increase in white matter compared to the baseline. Additionally, in a study by French doctors in Strasbourg, more than half of the 58 COVID-19 patients in intensive care suffered from neurological disorder and confusion, and their brain scans showed inflammation in the brain region. Although COVID-19 is known as a respiratory illness, such research shows that this disease can also affect the nervous system[5].

According to research by Holdsworth and colleagues in the UK in 2022, six months after infection, a specific focal cognitive impairment was identified in individuals with persistent symptoms of fatigue, poor concentration, weak memory, low mood, and anxiety. The cognitive assessment identified a specific deficiency equivalent to the legal limit for driving under the influence in the UK or the expected severity with a 10-year increase in age, which seems to significantly help in diagnosing long COVID symptoms[6]. The findings from studying 5428 participants in the online Robin memory test in December 2020, taking into account COVID status, age, time post-COVID, and persistent symptoms, indicate that COVID-19 has a negative impact on working memory performance in adults aged 25 and older, but not in the youngest age group (18 to 24 years). Furthermore, our results suggest that working memory impairment with COVID-19 can improve over time, although this disorder may persist in individuals with persistent symptoms[7]. Tavares et al. (2022) found a high prevalence of cognitive impairments following COVID-19 infection by reviewing 22 relevant articles[8].

Based on Beck and Flow's 2022 study, individuals with COVID-19 reported significantly more cognitive impairments compared to those without COVID-19. Additionally, COVID-19 infection had considerable indirect effects on cognitive failure, significantly impacting task performance and displacement goals. These results suggest that beyond physical damage, COVID-19 can have a detrimental effect on an individual's capacity to work in the workplace[9]. Nearly all COVID-19 patients exhibited significant cognitive impairments. A selective impairment was observed in the areas of visual-spatial/executive functioning, abstract thinking, attention, and delayed recall[10]. Individuals who have survived COVID-19 often complain of cognitive dysfunction, described as "brain fog"[11]. A significant concern in patients with Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) is the persistence of symptoms that continue for months after recovery. This condition is called Post-Acute COVID-19 Syndrome, long COVID, or Post-Acute Sequelae of COVID-19 (PASC). According to a study, one-third of patients experienced neurological or cognitive sequelae six months after recovering from COVID-19. Research involving 305 non-hospitalized COVID-19 patients to study late cognitive dysfunction and its relationship with initial symptoms found that cognitive scores for short-term memory, spatial visual processing, learning, and attention were below norms in a median of 11 months (range 8-13) after a positive PCR test. There was no correlation between the severity of initial symptoms and cognitive impairment[12]. Common symptoms of Coronavirus 2 (CoV-2) infection include severe acute respiratory syndrome (SARS) with pneumonia (COVID-19). However, SARS-CoV-2 can also impact the brain and cause chronic neurological symptoms known as long, post-acute, or persistent COVID. Up to 40% of patients are affected. Symptoms (fatigue, dizziness, headache, sleep disturbances, malaise, memory, and mood disorders) are usually mild and self-resolve. However, some patients may experience severe and fatal complications, such as stroke or encephalopathy. Damage to brain blood vessels due to the spike protein of Coronavirus (S protein) and overactive immune responses have been identified as the main causes of this disease. However, the molecular mechanism by which the virus affects the brain has not yet been identified[13].

In 2022, The Serano Psychiatric Research Group conducted an analytical study involving selective engagement of various cognitive domains and the presence of biological markers in a multicenter cross-sectional study of patients who had recovered from severe SARS-CoV-2 infection, sequentially selected between 90 and 120 days after discharge from the hospital. All patients underwent a comprehensive study of cognitive functions as well as determination of plasma pro-inflammatory, neurotrophic, and neuro-filament light chain factors. The study results show preferential engagement of episodic and working memory, executive functions, attention, and relatively less impact on other brain cortical functions[14]. Additionally, anxiety and depression scores remained stable in the group. Several plasma chemokine concentrations increased compared to both control groups, neurological outpatients without SARS-Cov2, or healthy general population. Patients with severe COVID-19 may experience memory deficits and maladjustment with neuropsychiatric manifestations. It is unclear whether the identified deficits can persist in the long term and if they can lead to the onset or acceleration of neurological diseases[15]. Patients with COVID-19 who report cognitive symptoms show cognitive impairment especially in areas of focus and executive function, episodic memory, and visual-spatial processing, highlighting the need for future studies to identify specific mechanisms related to cognitive dysfunction in COVID-19[16].

In a case study, a 45-year-old man who survived a severe COVID-19 illness, including acute respiratory distress syndrome (ARDS), brain micro-bleeds, and 35 days of mechanical ventilation, showed above-average results in tests measuring learning, memory, verbal fluency, and spatial functioning after an 8-month evaluation. Although he did not show any persistent psychiatric symptoms, partial deficits were found in logical reasoning, attention, executive function, and processing speed. Despite returning to a part-time job, he was unable to resume his previous activities, suggesting potential cognitive impairments following severe COVID-19 that require follow-up with neuropsychological tests sensitive to subtle deficits. The main findings of this report somewhat support the long-term prognosis of cognitive deficits in severe COVID-19[17].

One of the recent treatments used to improve cognitive function is cognitive rehabilitation therapy[18]. Cognitive rehabilitation therapy is a goal-oriented, multifaceted rehabilitation program designed to restore or compensate for cognitive skills and abilities that have been altered or lost after brain injury[19]. In particular, cognitive rehabilitation therapy focuses on improving cognitive functions (memory, attention, and concentration) and life skills. The main principle of cognitive rehabilitation therapy is brain plasticity, referring to the brain's specific capacity to reorganize and change the neural network's function by producing new synapses or eliminating older ones. Cognitive rehabilitation therapy helps individuals improve compensatory mechanisms by utilizing the brain's ability to perform complex tasks using alternative cognitive processes and focuses on reducing disability[18].

Individuals recovering from COVID-19 may still have persistent symptoms months after recovery. Moreover, in discharged patients, especially in the intensive care unit, due to clinical conditions resulting from immobility and specific hospital conditions, these consequences will double. Therefore, both persistent disease symptoms and post-discharge conditions require regular rehabilitation programs. These individuals can complement their rehabilitation programs in specialized or home-based rehabilitation sections to recover physical-movement function and improve their mental status[19-23]. Considering the long-term effects of COVID on cognitive functions and the lack of any systematic research in Iran addressing the impacts of the coronavirus on brain cognitive functions and the hindrance of a systematic process in the world for the improvement of COVID patients in working memory and attention areas which have been seriously affected by COVID-19 based on the findings articles published, the upcoming research would be an important and unique step towards evaluating COVID patients and their rehabilitation process. It is hoped that the results obtained will be an important step in determining and promoting the post-COVID therapeutic protocol in cognitive functions. Therefore, the main aim of this study is to determine the effectiveness of cognitive rehabilitation in improving working memory and attention in acute COVID-19 survivors.

Materials and Methods

The present study used a quasi-experimental design with a Pre-test Post-test and a control group. In this method, the experimental group underwent cognitive rehabilitation, while the control group was placed on a waiting list, and both groups took the pre-test and post-test simultaneously. The statistical population of this research included all individuals with acute COVID-19 in the city of Tehran. Considering the effect size of 0.3, the test power of 0.8, and the alpha value of 0.05, the sample size was estimated to be 30 using G-Power software. Therefore, based on inclusion and exclusion criteria, 36 individuals were selected as the sample using the purposive sampling method. These 36 individuals were randomly allocated into two groups of 18, experimental and control. The experimental group received cognitive rehabilitation, while the control group did not receive any intervention.

Criteria for entry into the study included having a minimum level of middle school education, being over 18 years old, obtaining more than 50% of the criteria in the persistent cognitive dysfunction symptoms of COVID-19 questionnaire (including problems with concentration, memory impairment, confusion, forgetfulness, dizziness, decision-making problems, difficulty in remembering new information, chronic fatigue, headaches, severe tiredness), willingness to participate in the research (informed consent).

Criteria for exiting the study also included receiving other concurrent therapeutic programs, presence of other cognitive disorders such as Alzheimer's and dementia, unwillingness to continue treatment, and absence of more than 2 sessions in the treatment process.

At the beginning of the study, a researcher-made questionnaire was distributed through social networks to examine the persistent symptoms of cognitive dysfunction resulting from COVID-19, and 470 individuals responded to this questionnaire. After scoring and examining other entry and exit criteria, 36 individuals were selected as the sample. For the sample individuals, in addition to explaining the purpose and importance of the research, ethical considerations were assured, and informed consent for participation in the study was obtained. Then, the individuals were randomly allocated into control and experimental groups, and pre-tests (working memory and attention tests) were conducted on both groups. The number and duration of each session were determined based on previous research studies in this field, usually ranging from 8 to 16 sessions lasting 40 to 60 minutes. Therefore, in this study, the rehabilitation program for the experimental group consisted of 12 sessions, each lasting 40 minutes and conducted three times a week. Based on the working memory and attention variables, programs related to three components (divided attention, working memory, and responsiveness) were selected and executed from the total of programs concerning memory and attention. The method of performing each of these tasks was carefully studied by the therapist and explained in simple and understandable language to the recovered COVID-19 patients. It is also worth mentioning that a specialist (supervisor) supervised the implementation of the treatment process and program adjustments. Each session had a different content compared to the previous session, motivating the participants to continue the treatment. Two stages were considered for each session in a way that if the participants completed the stages, they would progress to higher levels in the next sessions. One week after the completion of the intervention, both groups were reassessed for working memory and attention. The intervention procedure is described below:

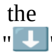
Due to the consultation and correspondence that took place, the payment for the exams (offline), the purchase of 100 hours of online therapy, and the selection of the experimental group, a software program was sent to each individual in the form of a CD. After instructions on installing the software, it was installed on the clients' computers or laptops with online support. A unique account for each individual based on a unique username and password (phone number) was created online on the server, and the group was informed through group and individual support. After ensuring the removal of installation barriers and activating rehabilitation programs on Saturdays, Tuesdays, and Thursdays each week, the therapy was activated. Before each exercise on selective attention, working memory, and responsiveness, instructional videos with detailed explanations were communicated in the therapy group, and exercises started from 8 am to 8 pm with online support for addressing and justifying issues.

The experimental group exercises were divided into three repeating and rotating sections: "divided attention," "working memory," and "responsiveness" with durations of 15 minutes, 20 minutes, and 10 minutes, depending on the progress of each participant's stages and the stage progress being regulated by Dr. Somayeh Pourmohammadi the day before the exercises. The progress stages of each client in each of the three rehabilitation sections of "divided attention," "working memory," and "responsiveness" were defined while overlapping 3 to 4 stages before the last stage achievement of the same exercise on the day before, so that the respondent would not face an easy challenge that they had previously exercised or a new challenge without preparation. All data collected from research questionnaires were analyzed using SPSS-26 software. Descriptive analysis of frequency distribution tables and central and dispersion indices such as mean and standard deviation were used to describe the data. Furthermore, inferential methods, including multivariable (MANCOVA) and univariable (ANCOVA) analyses of covariance, were used to investigate the research hypotheses. Before conducting multivariable covariance analysis, Box's M test, Smirnov-Kolmogorov test, and Levene's test were used to adhere to its assumptions. The results of Box's M test (P-value=0.048, F=1.677) showed that this value is statistically significant and indicates that the covariance matrices of the dependent variable are not equal to the independent variable level; thus, the homogeneity assumption of covariance matrices is not established as one of the assumptions of multivariable analysis of covariance. The Smirnov-Kolmogorov test for the selected attention, divided attention, and working memory variables is not significant (P-value>0.05), indicating that the variables have normal distributions. On the other hand, since one of the requirements for conducting covariance analysis is the homogeneity of variances among groups, Levene's test was used to test this assumption, and the results showed that Levene's test is not statistically significant for any of the variables (P-value>0.05); therefore, the hypothesis of homogeneity of variances is also valid, and parametric analyses can be used in this research.

RehaCom cognitive rehabilitation software: The RehaCom software is a comprehensive program that uses computer systems for cognitive rehabilitation. This software can help users improve their performance in tasks that require attention, concentration, memory, and perception. It consists of 29 modules in English and modules in 21 other languages. The "working memory" module teaches working memory, the ability to remember, manipulate presented information, and then delete it. The "responsiveness" module teaches attention, response control, and processing speed. The "divided attention and concentration" modules teach selective attention, divided attention, visual scanning, and response control to visual and auditory information. The "logical reasoning" module teaches executive functions and problem-solving. The "3D spatial operations" module teaches spatial awareness and spatial attention. These modules are used for all clients. RehaCom also has automatic adaptation capabilities, which means that the level of complexity and task difficulty automatically increases or decreases based on the participant's performance. RehaCom allows the therapist to monitor the participant's performance during the experiment. It can be used simultaneously by multiple therapists and participants. Only the therapist and participant need to define separate profiles. Another feature of RehaCom is the ability to adjust some variables for the therapist, aligning the therapist's knowledge and capabilities with the software. These parameters include the length of therapy sessions, the level at which the experiment starts, and the level of sensitivity to task adaptation for each participant[24].

In divided attention training, the client must control the movement of a train within a specific time and distance range. They should respond promptly and correctly to obstruction signals, speed limit signs, and various random announcements displayed on the control dashboard. In more advanced stages and in guiding the vehicle, it is necessary to adhere to the speed limit before seeing the sign to increase speed and respond to the "reduce speed limit" stimulus (for example, from 80 km/h to 60 km/h) before reaching the sign, turning on the gas light, turning on the oil light, turning right or left, and in more advanced cases, decreasing speed before turning and confusing signs in the landscapes; responses must be issued promptly. At the end of each stage, the number of erroneous reactions, late reactions, and wrong key presses would be reported on the display screen to inform the client, and if the performance is low and errors are high, the stage would be automatically repeated.

In working memory training, the participant first sees cards with special symbols and multiple colors at the top of the screen. After these cards are hidden, the correct cards requested by the software should be chosen from the new cards at the bottom of the screen and placed in their correct positions. This exercise progresses with each stage passed, entering a new level with more difficult tasks. For example, in the earlier stages, two opponent cards are displayed, then six cards as the stages progress, requiring the selection of a specific type of card, such as only yellow cards.

In the responsiveness exercise, the client should press the defined button according to the guide in each stage as soon as it is displayed on any part of the screen. For example, in one stage, when seeing the + sign, the individual should respond to the stimulus by pressing the "right arrow" button on the keyboard, and when seeing "" anywhere on the screen, they should respond by pressing the "up arrow" button. This exercise progresses from easier to more difficult symbols and becomes more challenging with the memorization of more than two symbols.

Results

In this study, the mean age of the participants in the experimental group was 42.27 with a standard deviation of 9.21, while in the control group, the mean age of the participants was 40.16 with a standard deviation of 5.86. No considerable differences were observed between the two groups in terms of age, education, employment status, and marital status (Table 1).

Table 1. Frequency of experimental and control groups based on demographic variables

Variable	Categories	Experimental group		Control group	
		Frequency	Percentage	Frequency	Percentage
Education	High-school diploma	2	11.1	2	11.1
	Associate degree	2	11.1	1	5.6
	Bachelor's degree	5	27.8	7	38.9
	Master's degree	7	38.9	6	33.3
	Doctorate degree	2	11.1	1	5.6
Gender	Male	7	38.9	8	44.4
	Female	11	61.1	10	55.6
Marital status	Single	6	33.3	7	38.9
	Married	12	66.6	11	61.1

Based on the data presented in Table 2, it appears that the means of the selective attention, divided attention, and working memory variables in the experimental group in the post-test phase show a noticeable difference compared to the pre-test phase, while the means of the research variables in the control group did not show much difference between the pre-test and post-test phases. These differences were thoroughly examined in the inferential data analysis section with more details.

Table 2. Mean and standard deviation of experiment and control groups, based on standard scores

Variable		Group	Pre-test		Post-test	
			Mean	Standard deviation	Mean	Standard deviation
Selective attention	Reaction speed	Experimental	-0.34	1.36	0.12	0.85
		Control	0.16	0.75	0.17	0.72
	Reaction control	Experimental	-1.23	1.66	-0.35	1.07
		Control	-0.87	1.24	-0.86	1.25
Divided attention	Auditory	Experimental	-0.73	1.61	0.34	0.28
		Control	0.05	0.54	0.08	0.52
	Visual	Experimental	-0.11	0.69	-0.02	0.78
		Control	0.18	0.27	0.19	0.32
Working memory		Experimental	-0.31	1.56	-0.25	1.09
		Control	-0.07	1.06	-0.06	1.08

Since in the Table 3 the Box's M test was significant, the result of the multivariate Pillai's trace has been reported, which is robust against the assumption of the variance-covariance matrix. According to this table of variable scores, there is a significant difference between research groups at the post-test stage (P-value<0.05). However, this significance does not indicate which variables the groups differ in; therefore, a univariate analysis of covariance has been used.

Table 3. Results of multivariate analysis of covariance to examine the impact of intervention on research variables

Test	d.f	F	P-value	Effect size	Test power
Pillai's trace	5	6.941	0.001	0.581	0.992

Based on Table 4, significant differences were found between the experimental and control groups in the subscales of reaction control and auditory divided attention (P-value<0.05). However, there were no significant differences between the experimental and control groups in the working memory variable and the visual divided attention and reaction speed subscales (P-value<0.05).

Table 4. Results of the univariate analysis of covariance to examine the effect of intervention on research variables

Variable		Source	Sum of squares	F	P-value	Effect size	Test power
Working memory		Group	1.014	1.532	0.226	0.050	0.224
Selective attention	Reaction speed	Group	0.739	2.090	0.159	0.067	0.278
	Reaction control	Group	5.060	5.578	0.025	0.161	0.627
Divided attention	Auditory	Group	0.767	5.115	0.031	0.150	0.590
	Visual	Group	0.075	0.239	0.629	0.008	0.076

Discussion

This study aimed to determine the effectiveness of cognitive rehabilitation in improving working memory and attention in acute COVID-19 survivors. The results showed no significant difference in working memory between the experimental and control groups. Therefore, the first sub-hypothesis is rejected. This result was consistent with the findings of Montoya-Murillo et al.,[21], Nazarboland et al.,[22], and Zare et al.,[23], but inconsistent with Varela-Aldás et al.,[25].

Möller et al., reported in a study titled "cognitive impairment in post-COVID-19 conditions: mechanisms, management, and rehabilitation" that long-term cognitive impairment is one of the most common disorders in post-COVID-19 conditions, affecting 17 to 28 percent of individuals more than 12 weeks after infection. In some cases, it may persist for several years, suggesting that rehabilitation interventions are necessary, and psychological training and compensatory skill training are recommended[26]. Cognitive rehabilitation may be effective for individuals who do not suffer from post-exertional malaise in specific attention and working memory disorders[19]. Mahrooghi et al. reported that cognitive rehabilitation effectiveness based on working memory enhancement improves information processing speed, but the effectiveness of cognitive rehabilitation therapy based on attention enhancement in the cognitive emotion regulation variable (positive strategies) has been more significant[27]. Varela-Aldás et al., in their study titled "memory rehabilitation during the COVID-19 pandemic", reported a significant improvement in neuropsychological assessment after intervention using two memory training techniques (paired-associate learning and loci method) on participants. The reason for these inconsistent results can be attributed to differences in intervention techniques and measurement instruments in the current study compared to Varela-Aldás et al.,[25].

In explaining the above findings, it can be stated that memory provides the necessary temporary storage and manipulation of information for complex cognitive tasks[24]. Memory allows individuals to store information in their minds and use it for problem-solving. This process is accompanied by the frontal lobe of the brain[23]. Cognitive rehabilitation methods focus on retraining cognitive functions through exercises, adaptation, implicit and explicit learning, and coping strategies. Computer-based cognitive training programs provide tools that help individuals improve basic cognitive processes that are important in high-level learning[28- 29]. On the other hand, according to Möller et al., one of the barriers to improving cognitive functions in recovered COVID-19 patients is post-exertional malaise[26]. Post-exertional malaise refers to worsening symptoms following physical or mental activity, which usually worsen 12 to 48 hours after activity and can continue for days or even weeks. This issue was observed in some of the participants in the present study, and it affected the research results. Another reason for such discrepancies in research results is attributed to individual differences among participants and the cognitive program used[26].

Based on the results, there is no significant difference between the experimental and control groups in the subscales of visual divided attention and reaction speed. However, in the subscales of auditory divided attention and reaction control, there is a significant difference between the experimental and control groups. Therefore, considering the means of research variables in the post-test phase, it can be concluded that cognitive rehabilitation can improve auditory divided attention and reaction control in acute COVID-19 recovered patients. This finding is consistent with the results of Kupferschmitt et al.,[29], Dutra et al.,[30], and Shafiei et al.,[31].

Kupferschmitt et al., reported in a study aimed at investigating the impact of rehabilitation on attention deficits and depression symptoms following COVID-19 that the intervention effectively reduced depression symptoms, but cognitive problems such as attention and working memory continued during the rehabilitation period despite the multifaceted therapy, with no comparable effect in the short 5-week period[29]. Dutra et al., showed in a study that cognitive rehabilitation intervention significantly reduced depression symptoms and increased intermittent attention in stroke patients. While it is accepted that some individuals may still show deficits in various aspects of attention, cognitive rehabilitation has helped improve the clinical condition of these individuals[30]. Shafiei et al. reported in a study that a cognitive rehabilitation program based on executive functions had an impact on the processing speed and attention of children with autism. According to these findings, the mentioned cognitive rehabilitation program has increased processing speed and improved attention in children with autism[31].

The above findings suggest that based on the principles of effective cognitive therapies such as cognitive rehabilitation, progress in individuals' skills can be made by providing extensive training, including repetition, exercise, and feedback that can be generalized to other activities, tasks, and related abilities. Attention is one of the most complex types of executive functions that require focus, optimal working memory function, and inhibitory control[32]. The learner's attention to the subject is one of the main factors in the learning process. Bandura emphasizes that learning begins with attention, and if there is not enough attention, the individual's learning is impaired. Individuals with attention difficulties cannot focus on tasks long enough, filter excessive stimuli, resist irrelevant and extraneous stimuli, and are very distracted. Executive functions and attention are among the abilities that individuals need for learning[33]. Cognitive rehabilitation programs, considered a form of learning experience, are designed to adapt brain function to daily activities[34]. Overall, based on the principle of the underlying mechanisms of brain plasticity, it can be concluded that the brain is a dynamic organ that has a high capacity for restructuring neural organization throughout life. The basis for behavioral changes and structural changes in the brain is hidden in dendritic and synaptic fields, and there is a possibility of improving neuronal function through cognitive exercises and structured brain stimulation[35]. On the other hand, the lack of significant changes in subscales of reaction speed and visual divided attention can be attributed to the short duration of therapy to induce changes, as Alemanno et al. (2021) stated that cognitive rehabilitation and psychological support should be considered in the long-term to be effective for patients after COVID-19[36].

Additionally, the results indicate that there is a significant difference between the experimental and control groups in the auditory divided attention and reaction control subscales. However, there is no significant difference between the experimental and control groups in the working memory variable and the visual divided attention and reaction speed subscales. This result is consistent with the findings of Kupferschmitt et al.,[29], Dutra et al.,[30], Shafiei et al.,[31], Hagen[37], and Delgado-Alonso[38].

Garcia-Molina et al.,[39] showed that all patients undergoing neuropsychological rehabilitation improved in memory tasks after treatment. Hospitalized patients also performed better on phonemic fluency tasks after intervention (this test is sensitive to changes in executive control, especially response initiation and maintenance, inhibition, organization, cognitive flexibility, and monitoring). It was also shown that after intervention, the likelihood of experiencing anxiety or depression symptoms decreased significantly. Hagan et al., in a study titled "cognitive rehabilitation in post-COVID-19 conditions: a controlled randomized trial protocol", showed that goal management training as a type of cognitive rehabilitation intervention can improve metacognition, executive functions, and secondary outcomes, including performance-based neuropsychological measures and tertiary outcomes such as cognitive rating scales, emotional health, quality of life, and fatigue[37]. It was determined that cognitive rehabilitation has a notable influence on the brain regions associated with cognitive skills, enhancing their functionality and serving as a suitable approach for enhancing cognitive abilities[30-37].

Typically, every research has limitations due to the conditions and resources under which the intervention took place, which can reduce its generalizability to the target population. The present study also has limitations that could somewhat diminish the generalizability of its results. Some of This research has some limitations. The study population is limited to individuals with acute COVID-19 in Tehran only, so caution should be exercised when generalizing it to other communities. Failure to examine long-term changes is another limitation. Given the timeframe of the study, it was not possible to investigate long-term changes resulting from the intervention, and only short-term changes were obtained. Another limitation of this research is conducting the study at the university level with limited resources and difficulties in recruiting participants as well as ensuring their retention until the end of the study.

According to current findings, cognitive rehabilitation can improve working memory and attention in acute COVID-19 survivors. It is therefore recommended to use this intervention in healthcare facilities and mental health clinics to improve cognitive functions in acute COVID-19 survivors.

Ethical Considerations

This paper was extracted from an MSc thesis in psychology. The study protocol was approved by the Ethics Committee of Islamic Azad University of South Tehran Branch (code: IR.IAU.STB.REC.1402.234).

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Conflict of Interest

There are no conflicting interests.

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