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Comparison of Working Memory, Cognitive Flexibility, and Sustained Attention in People with Previous COVID-19 Infection Who Have Recovered with Non-Infected Counterparts

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ABSTRACT

Introduction:
Many people experience persistent cognitive problems after COVID-19, with no current targeted treatments. This study compared working memory, cognitive flexibility, and attention in recovered COVID-19 patients versus non-infected peers to better understand these deficits.

Materials and Methods:
The study utilized a case-control and causal-comparative research design to explore cognitive differences related to COVID-19 severity. The participants were residents of Tehran divided into two groups: individuals who had not been affected by COVID-19 or experienced only mild cases, and those who had suffered from severe COVID-19 in 2023. The total sample consisted of 60 participants, with equal groups of 30 each, selected through convenience sampling. The methodology involved administering various memory assessments, including the N-Back, Wisconsin, and continuous performance tests, to evaluate cognitive function. For data analysis, an independent samples T-test was conducted in SPSS version 26 to compare cognitive performance between groups.

Results:
The recovered COVID-19 group had an average age of 40.57, while controls averaged 36.57. They scored lower in working memory (30.21 vs. 32.56, p=0.038) and cognitive flexibility (4.03 vs. 5.03, p=0.031). No significant differences were found in sustained attention, indicating it may remain unaffected post-recovery.

Conclusion:
COVID-19 recovery is linked to declines in working memory and flexibility. Interventions targeting these areas could aid recovery and improve quality of life. These differences were observed through measures of performance levels and survival rates. Based on these findings, it is recommended that interventions aimed at improving working memory and cognitive flexibility be implemented in hospitals and mental health centers.

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Introduction

In December 2019, a serious respiratory illness was identified in Wuhan, China, known as COVID-19. This respiratory condition, caused by severe acute respiratory syndrome, was devastating (1). According to Wu et al. there were 240 million confirmed cases worldwide, with a death toll exceeding 49 million (2). The most common symptoms experienced by patients with mild to moderate acute respiratory syndrome include headaches, coughing, and loss of smell. However, severely ill patients can experience brain damage, respiratory failure, stroke, metabolic dysfunction, as well as persistent changes in consciousness, and various forms of confusion following discharge from the hospital (3). Typically, individuals who have been infected with the COVID-19 virus for at least three months, with a history of probable or confirmed SARS-CoV-2 infection (with symptoms appearing at least two months prior), are considered to have COVID-19-related issues that cannot be explained by other diagnoses (4).

Research shows that a significant proportion of these patients experience neurological and psychiatric complications. Specifically, about 62% exhibit acute cerebrovascular events, such as strokes, while 59% continue to suffer from persistent psychiatric disorders—including delirium and seizures (5). Furthermore, approximately 20% of patients with neurological issues or cerebrovascular conditions require admission to the intensive care unit (ICU). Even after removal of medical devices, many patients face ongoing neurological problems and long-term health effects resulting from their illness (6). People infected with the virus have been experiencing an increase in neurological complications, with common symptoms such as confusion, impaired consciousness, and restlessness (7). Patients with COVID-19 have shown signs of encephalopathy, including dizziness, headache, anxiety, depression, stroke, and epileptic seizures. However, the exact cause of these neurological symptoms remains unknown. It has been observed that the long-term effects of COVID-19 are not limited to patients who were hospitalized in the ICU but also affect those who had mild infections and did not require hospitalization. Neurological complications from COVID-19 can result in damage to both the central and peripheral nervous systems (8,9). Cognitive functions refer to complex mental processes in the brain, including planning, working memory, attention, inhibitory control, self-monitoring, and self-regulation. The frontal and frontal lobe areas of the brain house these functions, which oversee intricate cognitive tasks and control different brain functions (10). Individuals with working memory disorders may experience significant challenges in their daily lives, and it is essential to seek guidance from a psychologist or doctor if any symptoms arise to maintain memory and cognitive function health (11). A study involving 214 participants aged between 26 and 64 examined cognitive disorders in a large sample of individuals experiencing post-COVID-19 syndrome, with a particular focus on executive functions. The results from assessments of sustained attention, working memory, and overall executive functions showed a higher prevalence of severe cognitive impairments among those infected during the COVID-19 pandemic.

Interestingly, the study also found that older patients tended to retain their cognitive abilities relatively well, with only mild impairments observed in areas such as sustained attention, working memory, and information processing speed. In contrast, younger patients demonstrated more significant and diverse cognitive impairments, indicating that age may influence the trajectory and severity of cognitive deficits following COVID-19 infection (12).

A recent comprehensive review pointed out that fatigue and cognitive decline are the most frequent and severe symptoms experienced by individuals 12 weeks after being diagnosed with COVID-19 (13). Specifically, 22% of patients reported cognitive impairment, which was determined through various methods such as a brief cognitive screening like the Montreal Cognitive Assessment, phone interviews, or an online survey (14). However, since many studies did not confirm the presence of cognitive impairment before to the COVID-19 diagnosis, it is uncertain how much of these outcomes are directly linked to the COVID-19 infection itself (15). Another analysis pointed out that cognitive impairments continued to persist at 6 months after the COVID-19 diagnosis in 20.2% of patients, along with anxiety in 19.1% and post-traumatic stress in 15.7% (16). There is still limited literature on the cognitive effects of COVID-19. Alemanno and colleagues conducted a study involving 87 COVID-19 patients and found that approximately 80% experienced significant cognitive impairments during the subacute phase of the illness. These impairments affected various cognitive domains, including memory, attention, abstraction, and spatial and temporal orientation. Furthermore, they observed that about 70% of these patients still showed signs of cognitive dysfunction one month after being discharged from the hospital (17). Similarly, Zhou et al. investigated the effects of COVID-19 on cognitive functions in recovered patients using neuropsychological assessments. Their findings indicated the presence of potential cognitive impairments, with a particular impact on sustained attention (18). These studies highlight the enduring cognitive challenges faced by many individuals following COVID-19 infection, emphasizing the importance of further research and targeted interventions. A study on 79 parents of children with Covid-19 showed a decrease in attention and working memory in children after contracting the virus. Parents reported a link between attention and working memory, but not with the severity of Covid-19 (19). The revealed that loneliness has a significant and positive predictive impact on psychological adjustment issues, with hope serving as a potential mediator. The relationship between loneliness and hope was found to be moderated by psychological flexibility (20). Moreover, research investigated the connections between psychological resilience, cognitive flexibility, and fear of COVID-19, including both direct and indirect relationships and any potential mediating effects. The results from this study emphasized the importance of psychological resilience as a mediator in the association between cognitive flexibility and fear of COVID-19 (21). Experimental studies indicate that approximately 25-30% of individuals who have had COVID-19 may experience persistent issues with sustained attention even 6 to 12 months after infection, regardless of how severe their illness was. Ongoing follow-up care and addressing psychological concerns have been shown to support recovery in these cases (22).

Additionally, psychological research suggests that some COVID-19 survivors find it challenging to perform long-term tasks that require sustained attention in their daily lives (23). Given the high transmissibility of the coronavirus and its potential impact on executive functions—particularly those governed by the prefrontal cortex—this study aims to investigate potential differences in cognitive functioning. Specifically, it seeks to compare working memory, cognitive flexibility, and sustained attention between individuals who have recovered from acute COVID-19 and those who have not been affected by the virus.

Materials and Methods

Study Design and Setting

The research utilized a case-control study and a causal-comparative design. This topic can be classified as a causal-comparative design because it involves comparing groups that are already existing based on their COVID-19 infection status—those who previously had COVID-19 and recovered versus those who have never been infected.

- The researcher examined whether there are differences in cognitive functions (working memory, cognitive flexibility, sustained attention) between these two groups.
- Pre-existing groups: The groups are naturally formed based on COVID-19 infection status, not manipulated by the researcher.
- Comparison of outcomes: The study compares the cognitive functions (dependent variables) between the two groups to see if previous infection might be associated with cognitive differences.
- Inability to manipulate infection status: The researcher cannot assign people to have

or not have COVID-19—it is an existing condition.

- The goal is to infer whether having had COVID-19 (the independent variable, though not experimentally manipulated) is potentially associated with differences in cognitive abilities (dependent variables). It's exploring an *association*, not causality, but the design is similar to causal-comparative because of the group comparison.

It focuses on individuals in Tehran who either did not contract COVID-19 or experienced a mild case, as well as those who had severe COVID-19 in 2023. To clarify, the "non-infected" group refers to individuals who have never contracted COVID-19—confirmed through testing or self-reporting—meaning they have no history or signs of infection. They serve as a true control group representing individuals unaffected by COVID-19.

The "mild COVID" group, on the other hand, includes participants who had confirmed COVID-19 infection but experienced mild symptoms or were asymptomatic. These individuals were infected but did not experience severe illness.

Participants and Sampling

To collect samples, the convenience sampling method was used. The participants were randomly divided into two groups using matching methods. In the matching process, efforts were made to select samples from individuals who were similar in terms of age, gender composition, marital status, and education level. In total, the two groups were created randomly with 30 participants each. The participants were chosen with a convenience sampling method. Participants were selected deliberately and communicated with virtually by utilizing an online questionnaire for screening.

Sixty participants (30 non-infected, 30 with a history of severe Covid) were selected for the study. Sample size adequacy was performed using G-Power software, considering $\alpha = 0.05$, effect size=0.5, and power test= 0.85.

To qualify for inclusion in the research, participants must have at least a basic education, be over 18 years old, and meet more than 60% of the criteria for persistent cognitive dysfunction symptoms related to COVID-19 (such as difficulty focusing, memory issues, confusion, forgetfulness, feeling disoriented, decision-making challenges, trouble recalling new information, chronic fatigue, headaches, and extreme tiredness) indicating a history of acute Covid-19.

- Clinical severity criteria: Such as respiratory distress, oxygen saturation below 90%, need for hospitalization or intensive care, and evidence of significant lung involvement (e.g., via imaging).
- Assessment tools: Sometimes, standardized severity scales or guidelines from health authorities (like WHO or CDC) are used to categorize severity levels.
- Usually, a specific clinical assessment form or medical record review determines severity.
- Some studies may use patient self-report questionnaires to gauge symptoms severity, but this is less common for formal classification.

our study employed specific tools, such as:

- A clinical severity scoring system,
- Medical records review

Those fulfilling less than 40% of the criteria for lasting cognitive dysfunction symptoms (including similar issues) will be categorized as non-infected or individuals with milder COVID-19. The study required participants to willingly participate by giving informed consent. Criteria for exclusion involved having conditions resulting from substance abuse, a past of inborn cognitive impairment, as well as existing neurological issues.

Gaining consent from participants to conduct tests without revealing their private information through coding and interpreting results afterward was crucial in research.

Tools/ Instrument

Describe the study tools here generally.

Working Memory Test (The N-back task): The N-Back test on the computer assesses cognitive skills such as attention control, decision-making, and information processing that are associated with executive functions. It is often utilized in neuroimaging research to stimulate brain activity in participants (24). During the test, individuals must press a designated key on the keyboard when a visual stimulus appears on the screen that is similar to the previous one or shows no resemblance. Working memory test scores (N-back test) vary based on age, experience, and the test type. Scores generally range from 0 to 100 percent, with scores above 70 percent indicating good working memory performance in research settings. The N-Back test consists of three stages:

- In back-1, the subject responds by pressing the key if the presented stimulus matches the previous one.
- In back 2, the subject presses the key if the presented stimulus matches the previous stimuli.
- In back 3, the subject presses the key if the presented stimulus matches the previous stimuli.

Before taking the test, participants undergo a learning and practice phase. The duration of the test is approximately 10 minutes (24). Data collected from the test includes the number of correct and incorrect responses, unanswered items, and the average speed of correct responses.

The N-Back test requires different cognitive processes like regulating focus, making choices, and handling external data. When performing the N-Back test, the central processor system experiences the most conflict in working memory. The Iranian reliability and validity of the N-Back test have been confirmed in prior studies (25).

The Wisconsin Card Sorting Test (WCST):

Grant and Berg developed a test in 1948 to assess executive functions, abstraction ability, and cognitive flexibility. This test is commonly used to evaluate frontal lobe function (26). It involves strategic planning, organized search, goal-oriented behavior, and impulse control.

It is considered the most effective tool for assessing executive performance in individuals with brain injuries. The test consists of 64 cards with different colored symbols - red triangle, green star, yellow cross, and blue circle. Each card contains one of the colors and one of the shapes, with the number of shapes varying from one to four. The participant's task is to arrange the cards according to a specific rule governing the main four cards. The test was discontinued when a subject completed all six sorting categories or sorted all 128 cards. The following quantitative measures: the global score, which ranges from a maximum of 128 to a theoretical minimum of 0, indicating that a lower score reflects better performance. Feedback is provided after each response, and the pattern changes after a series of correct answers without the subject's knowledge, requiring them to adapt. Two key measures are considered in scoring the test: the number of cards completed and the persistence error, which reflects cognitive inflexibility and frontal lobe impairment. The test has shown good reliability and validity in assessing cognitive deficits. A computerized version, designed by Shahgholian et al., was utilized in this study with satisfactory reliability coefficients (27).

The Stroop Color and Word Test (SCWT):

The primary objective of this assessment is to evaluate sustained attention and impulse control (28). Various versions of continuous performance tests have been developed for therapeutic and research purposes. T-Scores of 40 or less for word, color, and color-word are classified as "low," while scores above 40 are deemed "normal." In all versions, participants are required to focus on a simple set of visual or auditory stimuli and press a key when the target stimulus appears. The Persian format of the test includes 150 stimuli, with 30 (20%) being target stimuli and the remaining 80% being non-target stimuli. Each stimulus lasts for 200 milliseconds with a one-second interval between stimuli.

The test involves identifying errors of omission and errors of commission. Omission errors occur when the participant fails to respond to the target stimulus, indicating difficulty in stimulus comprehension and attention stability. Commission errors happen when the participant responds to a non-target stimulus, showing weaknesses in impulse inhibition and impulse control. The computer program records and tallies these errors, along with correct responses and reaction times to stimuli. The continuous performance test software, developed by the Sinai Institute of Cognitive Sciences, has been validated and deemed reliable, with a reported reliability of 0.93 (29).

Data Collection Process

With permission from the university, participants were directed to Sina Hospital for data collection. According to hospital guidelines, anyone showing COVID-19 symptoms was advised to confirm infection through testing facilities and phone consultations before seeking hospital care. After obtaining ethical approval, hospital records were reviewed to identify two groups:

- COVID-negative individuals
- Recovered COVID-19 patients

Contact information for 94 individuals—comprising both recovered patients with medical records and asymptomatic contacts—was obtained from relevant personnel. Participants were informed about the study's purpose via phone calls and provided with details to ensure transparency.

Out of these, 54 individuals had recovered from COVID-19, while 40 were suspected contacts who tested negative. To verify if any recovered patients experienced severe COVID-19, the following criteria were reviewed:

Criteria for Severe COVID-19

1. Clinical Documentation:

- Hospitalization due to COVID-19
- Blood oxygen saturation (SpO_2) below 90% at any point during illness
- Requirement of respiratory support such as supplemental oxygen, mechanical ventilation, or ICU admission
- Imaging results indicating extensive lung involvement (chest X-rays or CT scans)
- Severe symptoms like significant breathlessness, chest pain, or extreme fatigue

2. Diagnostic Guidelines: Comparison against standard severity definitions from authoritative sources:

- WHO guidelines: Severe illness includes symptoms like respiratory distress, $SpO_2 < 90\%$, or pneumonia with complications
- CDC guidelines: Similar criteria based on clinical signs and oxygen levels

3. Case File Review:

- Confirm documentation of severe symptoms
- Evidence of interventions like ICU admission or mechanical ventilation

4. Consistency Check:

- Ensuring that all patients classified as 'severe' meet at least one of these criteria

Data Collection Methods

Data was gathered via online platforms—WhatsApp and Skype—using structured questionnaires. Participants were contacted after receiving ethical approval, ensuring their responses would be confidential and voluntary. Participants were reassured that they could withdraw at any time without penalty, respecting their autonomy and fostering trust.

Before participation, detailed information about the study’s purpose, procedures, potential risks, and benefits was provided. Informed consent was obtained from each participant.

The questionnaires were completed in real time during an online session, with the researcher present to facilitate and clarify any questions. This setup allowed for immediate interaction and ensured data completeness.

Communication Platforms & Duration

Using WhatsApp and Skype ensured easy access for participants, regardless of location, reducing technological barriers and increasing convenience. The questionnaires were designed to take approximately 20 to 35 minutes, a duration that balances thoroughness with participant comfort to reduce fatigue and maintain engagement.

Data Analysis

The study utilized descriptive statistics to examine indicators and variability of main and demographic variables. The chi-square tests were used to compare demograghic variables. In the inferential statistics section, the Kolmogorov-Smirnov and Levene’s tests were employed to verify assumptions, followed by T-test. Data analysis was conducted using SPSS software version 26.

Results

The average age of participants in the recovered patient's group was (40.57±6.73) and in the healthy group, it was (36.57±7.62). The youngest individual was 23, while the oldest was 61 years old. Regarding demographic characteristics, there were more women than men in the study, with 19 women (63.3%) in the patient group and 17 women (56.7%) in the healthy group. Most participants had a university education, with 20 individuals (66.66%) in the patient group and 22 individuals (73.3%) in the healthy group. Additionally, most participants were married, with approximately 21 individuals (70%) in each group.

Table 1: Frequency of two groups of acute corona recoveries and non-infected counterparts based on demographic variables

Variable	Groups	Acute corona recoveries		Non-infected counterparts		
		F	percentage	F	percentage	P-value
Gender	Male	11	36.7	13	43.3	0.425
	Female	19	63.3	17	56.7	
Education	No university education	10	33.33	8	26.7	0.408
	University educated	20	66.66	22	73.3	
Marital status	Single	9	30	9	30	0.632
	Married	21	70	21	70	

Table 2: Information about the mean and standard deviation of the two groups of acute corona recoveries and non-infected counterparts

Variable		Acute corona recoveries	Non-infected counterparts	P
		Mean± SD	Mean± SD	
Working memory		30.21±2.44	32.56±2.31	0.038
Cognitive flexibility	Number of floors	4.03±2.05	5.03±1.37	0.031
	In survival	5.27±4.43	2.53±2.59	0.005
Sustained attention	Error providing response	0.13±0.346	0.50±2.01	0.330
	Delete reply	0.07±0.254	0.47±1.69	0.207
	correct answer	48.13±9.10	49.03±2.61	0.605
	Response time (milliseconds)	428.37±111.67	431.72±54.11	0.906

Table 2 shows that the mean (SD) scores for working memory in individuals recovering from acute coronavirus (30.21±2.44) and non-infected individuals (32.56±2.31) differ significantly (p=0.038). Similarly, cognitive flexibility scores differ between the two groups, with acute recoveries scoring 4.03±2.05 and non-infected individuals scoring 5.03±1.37. There is no significant difference in sustained attention components between acute corona recoveries and non-infected individuals. The Error providing response scores are 0.13±0.346 for acute recoveries and 0.50±2.01 for non-infected (p=0.330). The Delete reply scores are 0.07±0.254 for acute recoveries and 0.47±1.69 for non-infected (p=0.207). The Correct answer scores are 48.13±9.10 for acute recoveries and 49.03±2.61 for non-infected (p=0.605). Lastly, the Response time is 428.37±111.67 for acute recoveries and 431.72±54.11 for non-infected, with no significant difference (p=0.906).

Discussion

The goal of this study was to do a comparison of working memory, cognitive flexibility, and sustained attention between individuals who have recuperated from COVID-19 and those who have not been affected by the virus. According to the findings, there is a significant difference in working memory capacity between individuals who have recuperated from acute coronavirus and those who have not been infected. The group of non-infected individuals displayed higher working memory scores compared to the group of recovered individuals. This outcome aligns with the findings of previous studies conducted by Cui et al. (30), Velichkovsky et al. (31), Kumar et al. (32), but contradicts the research by Chang et al (33). In contrast, Cui et al. (2024) demonstrated in their study that COVID-19 may lead to a decline in working memory capacity, frequently accompanied by neurological symptoms (30). Velichkovsky et al. (2023) highlighted in a literature review that patients with COVID-19 are at risk for deficits in short-term verbal working memory, and potentially in visual short-term memory and sustained attention (31). Conversely, Chang et al. (2023) suggested that individuals who have recovered from COVID-19 may engage in compensatory neural processes involving greater use of different brain regions and network reorganization to sustain normal working memory function (33).

The discrepancies observed in the results can likely be attributed to the differing methods used to assess working memory across the two studies. Chang et al. (2023) employed advanced neurological tools such as MRI and PET scans, which provide detailed insights into brain structure and function. In contrast, the current study relied on the N-Back task, a behavioral measure that evaluates working memory through task performance (33).

Memory plays a vital role in temporarily storing and processing information necessary for performing complex cognitive tasks. It enables individuals to retain information in their minds and effectively use it for problem-solving and decision-making. This cognitive function is primarily associated with activity in the frontal cortex of the brain (34).

Furthermore, memory impairments following recovery from COVID-19 can resemble those seen in individuals who have survived other severe illnesses, such as cancer or HIV. These impairments often affect various aspects of cognition, including short-term memory, working memory, language skills, and processing speed (31). Recognizing these similarities underscores the importance of comprehensive cognitive assessment and targeted interventions for COVID-19 survivors experiencing such challenges.

The neurological perspective suggests that changes in grey and white matter are the root cause of these cognitive impairments, which can develop early in the course of treatment due to elevated cytokine levels or hormonal changes, and persist for at least a year after treatment has stopped (35). Neuroinflammation can lead to functional and cognitive problems, with memory, attention, and processing speed being the most affected cognitive functions (36). Significant elevation in cytokine levels (such as interleukin-6, tumor necrosis factor-alpha, interleukin-1beta) in COVID-19 patients can lead to neuroinflammation, which is considered a key factor in causing memory and attention deficits (37).

Studies indicate a possible connection between stress hormones and short-term memory decline in individuals (30). Elevated levels of cortisol have been linked to memory problems as individuals age. While a temporary surge in cortisol is essential for survival, prolonged exposure to high levels of cortisol due to chronic stress can have detrimental effects. Research suggests that excessive levels of cortisol may contribute to the gradual deterioration of synapses in the frontal cortex, the region responsible for short-term memory retention. Given the severe and prolonged stress associated with COVID-19, it is likely that individuals with acute coronavirus symptoms are at a higher risk of experiencing memory loss compared to others (25,26). The findings reveal a significant difference in cognitive flexibility scores between individuals who have recovered from acute coronavirus and those who have not been infected. Specifically, the group that recovered from COVID-19 shows higher survival rates and fewer errors compared to the non-infected group, indicating better cognitive flexibility. Conversely, the non-infected group exhibits higher error rates, suggesting less cognitive adaptability.

These results support the second hypothesis, confirming that cognitive flexibility differs between the two groups. The findings are consistent with the study by Godara et al. (2023), which highlighted that cognitive control and flexibility play a crucial role in helping individuals cope with the adverse effects of the pandemic, fostering resilience and reducing stress (37). Overall, this emphasizes the importance of cognitive flexibility as a protective factor in post-COVID recovery, contributing to improved mental and cognitive health outcomes. Frolli et al. (2021) also highlighted the impact of viral infections and hospitalization on cognitive performance, particularly on working memory and flexibility. Further research on cognitive flexibility in acute coronavirus patients is necessary to gain more comprehensive insights into these changes (38).

In individuals suffering from acute coronavirus, the presence of erratic thought patterns and heightened anxiety leads to decreased cognitive flexibility compared to those who are not affected, preventing them from modifying their understanding of the illness and associated beliefs like others can. Additionally, there is no significant difference in the scores of sustained attentions between individuals who have recovered from acute COVID-19 and those who have not been infected. Therefore, when examining the components of sustained attention, including response errors, response omissions, correct responses, and response times, no significant differences were found between the two groups. As a result, the third hypothesis has been negated. These findings align with the conclusions drawn by Velichkovsky et al. (31), Öztürk et al. (21) and Godara et al. (37) but contradict the findings of Darvische et al. (2023). Previous research pointed out that the cognitive impact of COVID-19 varies depending on the evaluations conducted, emphasizing the need for a comprehensive cognitive assessment in individuals to detect potential neurological disorders and explore the unknown effects of the disease on cognitive functions like attention (12-15).

The variations observed in these results may be due to several factors, including differences in assessment tools, the duration of hospital stays, the time elapsed since recovery, and other influencing variables (16-18). Attention is a complex mental process that involves focusing on a specific target, engaging with it, and maintaining concentrated effort over an extended period (20-22).

Self-sustained attention, in particular, consists of two key components: observation or listening, and mental control or memory. Individuals who find it difficult to sustain attention for prolonged periods may experience attention deficits. Moreover, some cognitive and emotional issues can persist even after recovering from the acute symptoms of COVID-19. These lingering problems could be attributed to factors such as hypoxia resulting from pneumonia, central nervous system infections, or microstrokes (23-25).

However, research indicates that only about 11% of individuals post-COVID-19 experience attention deficits, suggesting that attentional impairments are not among the most prevalent or primary cognitive impairments associated with the disease (40). This highlights that while attention difficulties can occur, they are relatively less common compared to other cognitive effects in COVID-19 survivors.

Limitations and Suggestions

The current study employed a causal-comparative methodology, which involves inferring causality from observed effects; however, this approach makes it challenging to establish definitive causal relationships among the variables studied. The statistical population was limited to individuals residing in Tehran who either did not experience COVID-19 or had a mild form of the illness, as well as those who had previously recovered from acute COVID-19 in 2023. Consequently, caution is needed when generalizing the findings to other groups, and further research is necessary to broaden applicability.

One notable limitation of this study is the absence of an examination of long-term effects, primarily due to the specific timeframe of the research, which did not allow for assessment of enduring changes or impacts post-intervention. Additionally, the use of convenience sampling and a relatively small sample size may restrict the generalizability of the results and could introduce selection bias.

For future exploration, researchers interested in this field are encouraged to investigate other cognitive variables that might influence outcomes. It is also recommended to conduct longitudinal studies involving multiple cases of individuals with acute COVID-19 to achieve more accurate and comprehensive results over time. Lastly, applying these findings to broader populations across different cities and including individuals with chronic COVID-19 could help develop long-term strategies aimed at improving overall societal health and resilience against the pandemic's effects.

Conclusion

The study reveals a significant difference in working memory and cognitive flexibility—assessed through metrics such as the number of levels achieved and survival rates—between individuals who have recovered from acute coronavirus and those who have not been infected. These findings suggest that COVID-19 infection may adversely impact certain aspects of cognitive functioning. Based on this, it is recommended that interventions focused on improving working memory and cognitive flexibility be incorporated into healthcare settings and mental health clinics. Such interventions could help enhance cognitive resilience and overall mental functioning in patients recovering from acute coronavirus, potentially mitigating long-term cognitive deficits associated with the illness.

Ethical Considerations

The study with participants abided by the ethical standards set by the Tehran Branch, Islamic Azad University using the code IR.IAU.CTB.REC.1403.243.

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Conflict of Interest

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References

1. Islam A, Ahmed A, Naqvi IH, Parveen S. Emergence of deadly severe acute respiratory syndrome coronavirus-2 during 2019–2020. Virus disease. 2020;31(2):128-36.
2. Wu F, Zhao S, Yu B, Chen YM, Wang W, Song ZG, Hu Y, Tao ZW, Tian JH, Pei YY, Yuan ML, Zhang YL, Dai FH, Liu Y, Wang QM, Zheng JJ, Xu L, Holmes EC, Zhang YZ. A new coronavirus associated with human respiratory disease in China. Nature. 2020;579(7798):265-269.
3. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X, Cheng Z, Yu T, Xia J, Wei Y, Wu W, Xie X, Yin W, Li H, Liu M, Xiao Y, Gao H, Guo L, Xie J, Wang G, Jiang R, Gao Z, Jin Q, Wang J, Cao B. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10223):497-506.
4. Soriano JB, Murthy S, Marshall JC, Relan P, Diaz JV; WHO Clinical Case Definition Working Group on Post-COVID-19 Condition. A clinical case definition of post-COVID-19 condition by a Delphi consensus. Lancet Infect Dis. 2022;22(4): e102-e107.
5. Varatharaj A, Thomas N, Ellul MA, Davies NWS, Pollak TA, Tenorio EL, Sultan M, Easton A, Breen G, Zandi M, Coles JP, Manji H, Al-Shahi Salman R, Menon DK, Nicholson TR, Benjamin LA, Carson A, Smith C, Turner MR, Solomon T, Kneen R, Pett SL, Galea I, Thomas RH, Michael BD; CoroNerve Study Group. Neurological and neuropsychiatric complications of COVID-19 in 153 patients: a UK-wide surveillance study. Erratum in: Lancet Psychiatry. 2020;7(10): e64.
6. Chen T, Wu D, Chen H, Yan W, Yang D, Chen G, Ma K, Xu D, Yu H, Wang H, Wang T, Guo W, Chen J, Ding C, Zhang X, Huang J, Han M, Li S, Luo X, Zhao J, Ning Q. Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. BMJ. 2020;368:m1091.
7. Helms J, Kremer S, Merdji H, Clere-Jehl R, Schenck M, Kummerlen C, Collange O, Boulay C, Fafi-Kremer S, Ohana M, Anheim M, Meziani F. Neurologic Features in Severe SARS-CoV-2 Infection. N Engl J Med. 2020;382(23):2268-2270.
8. Lovell N, Maddocks M, Etkind SN, Taylor K, Carey I, Vora V, Marsh L, Higginson IJ, Prentice W, Edmonds P, Sleeman KE. Characteristics, Symptom Management, and Outcomes of 101 Patients with COVID-19 Referred for Hospital Palliative Care. J Pain Symptom Manage. 2020; 60(1): e77-e81.
9. Mao L, Jin H, Wang M, Hu Y, Chen S, He Q, Chang J, Hong C, Zhou Y, Wang D, Miao X, Li Y, Hu B. Neurologic Manifestations of Hospitalized

Patients with Coronavirus Disease 2019 in Wuhan, China. JAMA Neurol. 2020;77(6):683-690.
10. Goldstein S, Naglieri JA, Princiotta D, & Otero TM. Introduction: A History of Executive Functioning as a Theoretical and Clinical Construct. In S. Goldstein & J. A. Naglieri (Eds.), Handbook of Executive Functioning 2014; (pp. 3-12). New York, NY: Springer New York.
11. Songco A, Patel SD, Dawes K, Rodrigues E, O'Leary C, Hitchcock C, Dalgleish T, Schweizer S. Affective working memory in depression. Emotion. 2023;23(6):1802-1807.
12. Herrera E, Pérez-Sánchez MDC, San Miguel-Abella R, Barrenechea A, Blanco C, Solares L, González L, Iza C, Castro I, Nicolás E, Sierra D, Suárez P, González-Nosti M. Cognitive impairment in young adults with post COVID-19 syndrome. Sci Rep. 2023;13(1):6378.
13. Toussaint LL, Bratty AJ. Amygdala and Insula Retraining (AIR) Significantly Reduces Fatigue and Increases Energy in People with Long COVID. Evid Based Complement Alternat Med. 2023; 2023:7068326.
14. Cristillo V, Pilotto A, Cotti Piccinelli S, Bonzi G, Canale A, Gipponi S, Bezzi M, Leonardi M, Padovani A; Neuro Covid Next Study group. Premorbid vulnerability and disease severity impact on Long-COVID cognitive impairment. Aging Clin Exp Res. 2022;34(1):257-260.
15. Bertuccelli M, Ciringione L, Rubega M, Bisiacchi P, Masiero S, Del Felice A. Cognitive impairment in people with previous COVID-19 infection: A scoping review. Cortex. 2022; 154:212-230.
16. Badenoch JB, Rengasamy ER, Watson C, Jansen K, Chakraborty S, Sundaram RD, Hafeez D, Burchill E, Saini A, Thomas L, Cross B, Hunt CK, Conti I, Ralovska S, Hussain Z, Butler M, Pollak TA, Koychev I, Michael BD, Holling H, Nicholson TR, Rogers JP, Rooney AG. Persistent neuropsychiatric symptoms after COVID-19: a systematic review and meta-analysis. Brain Commun. 2021;4(1): fcab297.
17. Alemanno F, Houdayer E, Parma A, Spina A, Del Forno A, Scatolini A, Angelone S, Brugliera L, Tettamanti A, Beretta L, Iannaccone S. COVID-19 cognitive deficits after respiratory assistance in the subacute phase: A COVID-rehabilitation unit experience. PLoS One. 2021 Feb 8;16(2): e0246590.
18. Zhou H, Lu S, Chen J, Wei N, Wang D, Lyu H, Shi C, Hu S. The landscape of cognitive function in recovered COVID-19 patients. J Psychiatr Res. 2020; 129:98-102.
19. Frolli A, Ricci MC, Di Carmine F, Lombardi A, Bosco A, Saviano E, Franzese L. The Impact of COVID-19 on Cognitive Development and Executive Functioning in Adolescents: A First Exploratory Investigation. Brain Sci. 2021;11(9): 1222.
20. Gubler DA, Makowski LM, Troche SJ, Schlegel K. Loneliness and Well-Being During the Covid-19 Pandemic: Associations with Personality and Emotion Regulation. J Happiness Stud. 2021;22(5):2323-2342.
21. Öztürk ŞB, Akbayır SB. The Mediator Role of Psychological Resilience in the Relationship of Cognitive Flexibility and Fear of COVID-19. Journal of Family Counseling and Education.2020; 8(1):41-56.
22. Jun J, Toh YN, Sisk CA, Remington RW, Lee VG. Do concerns about COVID-19 impair sustained attention? Cogn Res Princ Implic. 2021;6(1):41.
23. Arbula S, Pisanu E, Bellavita G, Menichelli A, Lunardelli A, Furlanis G, Manganotti P, Cappa S, Rumiati R. Insights into attention and memory difficulties in post-COVID syndrome using standardized neuropsychological tests and experimental cognitive tasks. Sci Rep. 2024;14(1):4405.
24. Jaeggi SM, Buschkuehl M, Perrig WJ, Meier B. The concurrent validity of the N-back task as a working memory measure. Memory. 2010; 18(4): 394-412.
25. Miri Ashtiani SN, Daliri MR. Identification of cognitive load-dependent activation patterns using working memory task-based fMRI at various levels of difficulty. Sci Rep. 2023;13(1):16476.
26. Grant DA, Berg E. A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. Journal of experimental psychology. 1948;38(4):404.
27. Shahgholian M, Azadfallah P, Fathi-Ashtiani A, Khodadadi M. Design of the Wisconsin Card Sorting Test (WCST) computerized version: Theoretical fundamental, developing and psychometrics characteristics. Clinical Psychology Studies. 2012; 1(4): 110-134.
28. eukert X, Steindorf K, Schagen SB, Runz A, Meyer P, Zimmer P. Hippocampus-Related Cognitive and Affective Impairments in Patients With Breast Cancer-A Systematic Review. Front Oncol. 2020;10:147.
29. Mena-Vázquez N, Ortiz-Márquez F, Ramírez-García T, Cabezudo-García P, García-Studer A, Mucientes-Ruiz A, Lisbona-Montañez JM, Borregón-Garrido P, Ruiz-Limón P, Redondo-Rodríguez R, Manrique-Arija S. Impact of inflammation on cognitive function in patients with highly inflammatory rheumatoid arthritis. RMD open. 2024;10(2):e004422.
30. Godara M, Everaert J, Sanchez-Lopez A, Joormann J, De Raedt R. Interplay between uncertainty intolerance, emotion regulation, cognitive flexibility, and psychopathology during

the COVID-19 pandemic: a multi-wave study. Sci Rep. 2023;13(1):9854.
31. Frolli A, Ricci MC, Di Carmine F, Lombardi A, Bosco A, Saviano E, Franzese L. The impact of COVID-19 on cognitive development and executive functioning in adolescents: a first exploratory investigation. Brain sciences. 2021;11(9):1222.
32. Crivelli L, Calandri I, Corvalán N, Carello MA, Keller G, Martínez C, Arruabarrena M, Allegri R. Cognitive consequences of COVID-19: results of a cohort study from South America. Arq Neuropsiquiatr. 2022 Mar;80(3):240-247.
33. Wang W, Cui R, Leng L, Wang G, Peng G. Cognitive Impairment in the Post-Acute Phases of COVID-19 and Mechanisms: An Introduction and Narrative Review. J Alzheimers Dis Rep. 2024;8(1):647-658.